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Presentata da: INNA KRACHKOVSKAYA

Coordinatore Dottorato PROF. ANDREA MELIS

Tutor/Relatore PROF. RICCARDO DE LISA

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Abstract

In 2007-08, the world experienced the greatest financial crisis since 1929, which turned – in the following years – in one of the deepest and most prolonged periods of economic stagnation of modern history. While there were multiple conditions that originated the so-called Great Financial Crisis, a general consensus emerged that financial derivatives played an important role in the outbreak of the crisis and in posing a credible threat that the entire global financial system could melt down. As a reaction, several countries in the world and international organizations agreed on a policy response to reformulate the global architecture for the regulation of the financial system, including the financial derivatives industry. Yet, the fundamental question of whether the contemporary system of derivatives regulation can effectively shield the financial system from sources of systemic risk is still undecided, for reasons that especially relate to the complexity of the networked structure of the financial derivatives industry. As a way to contribute to tackle this issue, this work aims to investigate whether an important component part of the present system of financial derivatives regulation – namely, Central Counterparts (CCPs) Clearing Houses – provide a more resilient financial system. The research question is addressed through a simulation approach based on an agent-based modeling of the financial derivatives industry. The results of the simulation show that the introduction of a CCP improves the resilience of the simulated financial derivatives industry, although it does not completely shield the financial system from disruptions that may especially depend from the degree of interconnectedness of financial operators and the magnitude of defaults. In sum, this work offers some methodological guidance for enriching the repertoire of tools at disposal of financial regulatory authorities in anticipating the consequences of interventions in the financial industry.

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Chapter 1

Introduction

In 2007-08, the world experienced the greatest financial crisis since 1929, which turned – in the following years – in one of the deepest and most prolonged periods of economic stagnation of modern history. While many explanations have been put forward to account for the causes of the so-called Great Financial Crisis, a general consensus emerged that financial derivatives played an important role to create, first, the conditions for the crisis to happen and, then, to facilitate the escalation of defaults in the US sub-prime mortgage industry to the threat of a meltdown of the global financial system. During the 2010's, several countries in the world and super-national organizations aimed to reconfigure the regulation of the financial system in a way that included, *inter alia*, stricter regulation of derivatives. At the time of writing, the present regime of financial regulation is still evolving at different pace and coordinated efforts in various countries, but the issue of whether the new financial regulatory architecture provides solid foundations for making the financial system immune from new crises in the future is still unresolved.

Financial derivatives have long played an important role in the working of the market economy, especially in protecting traders from the risks related to fluctuations of prices of commodities, exchange rates, and interest rates. The emergence of neo-liberalist policies in the 1980's especially in the US and the UK, however, progressively lifted up regulatory barriers that had limited the extent to which financial derivatives could be used to perform additional functions, including opportunities for arbitrage and speculative investment. Together with the tendencies to the globalization of finance and the concentration of market power in relatively few large financial institutions, the deregulation of financial derivatives resulted in the monumental growth of the financial derivatives markets and in the formation of an 'opaque' network of financial derivative contracts. Financial regulators became unable to effectively monitor the concentration of risks and anticipate the aggregated consequences of potential default events. When the Great Financial Crises erupted, it became clear that – without any checks on their conduct – financial institutions had created

concatenations of financial derivatives contracts that had come to expose the financial system to sources of systemic risk. Financial derivatives – colorfully characterized by American investor Warren Buffet as “financial weapons of mass destruction” – took a central place in the concerns of policy-makers as central objects of regulation if the stability of the financial system was to be preserved.

The contemporary regime of financial regulation includes various instruments that are intended to prevent financial crises that can occasionally affect individual financial institutions or parts of the financial system and to protect the financial system from sources of systemic risk (i.e., so-called macro-prudential regulation). Many of these tools provide the means for regulating derivatives and derivatives markets, both in relation to the finely structured organization of standardized derivative products and to the more heterogeneous and – until the Great Financial Crisis – largely unregulated trade of so-called Over-The-Counter (OTC) derivatives. Among the tools for the regulation of financial derivatives, the introduction of Central Counterparts (CCPs) is a relatively innovative means of reconfiguring the network of financial derivative contracts. CCPs are expected to provide greater resilience of the financial systems to shocks that could – in principle – threaten financial stability. CCPs are financial institutions that play the role of intermediaries between two parties that – in their absence – would directly trade derivatives with each other. By substituting (through ‘novation’) an existing derivative contract between two counterparts with two contracts having each a CCP as counterpart, the presence of CCPs can result in better monitoring, supervision, and safeguards that derivatives are executed – especially, because the CCPs would act as ‘guarantors’ for the obligations that one counterpart of the derivative contract might not be able to fulfill.

The capacity of CCPs to counteract sources of systemic risk, however, is still controversial. CCPs may, in principle, ‘absorb’ or ‘cushion’ the financial system from losses that originate from financial derivatives and that can spread throughout the network of derivative contract counterparts. CCPs, however, may not effectively protect the financial system from the consequences of relatively unlikely – but still possible – events, such as the occurrence of losses that hit financial institutions that are highly interconnected with the rest of the financial system and the possibility that relatively large losses disrupt the stability of particular financial operators. The aim of this study is precisely to address the questions of whether CCPs are able to effectively perform a stabilizing role when facing

some of the actual conditions under which financial market operate, e.g., the high level of connectivity between financial institutions (that engage in multiple derivative contracts to hedge their positions and for speculative purposes), the presence of both systemic and institution-specific shocks, and the possibility that relatively large defaults impair the stability of the whole financial system.

The aim of this study is attained through a simulation approach based on agent-based modeling methodology. The choice for this particular – and relatively novel and rarely implemented – methodology originates from the relevance of agent-based modeling for investigating the aggregated behavior of complex system such as, precisely, the financial derivatives industry. The financial derivatives industry presents some of the typical features of complex systems. The financial derivatives industry is populated by heterogeneous actors, the structure of the industry is articulated in a networked form, and the dynamics of the industry is one where past events have important feedback effects that influence the trajectory of the industry in the future. Complex systems have particular properties, such as, for instance, that their dynamic trajectory is highly sensible to initial conditions and that the aggregated behavior of the system can present irregularities and discontinuities. The financial derivatives industry presents such traits: because of the interconnectedness between financial institutions, losses on any particular derivative contract may escalate into larger repercussions on a wider number of financial institutions and the magnitude of such disruptions may appear in a largely unanticipated way.

This study contains the development of an agent-based model of financial derivatives industry that includes an algorithmic computation of trades of derivative contracts and of the consequences of losses that originate from random events. The model is constructed with specific reference to credit protection derivative contracts (i.e., swaps) that take place between banks and other financial institutions (credit protection sellers), which, in turn, can trade (re-protect) their exposure to credit default risk with other financial institutions. The model is developed in two variants, that either only include banks and credit protections sellers (Model A) or include banks, credit protection sellers, and CCPs (Model B). By contrasting and comparing the different trajectories of aggregated behavior of the simulated financial derivatives industry (i.e., number of financial institutions and total amount of credits, assets, and reserves of the financial institutions involved), the simulation provides

some evidence that can assist the evaluation of the expected effects of the presence of CCPs on the stability of the financial system on the whole.

The rest of the work is organized as follows. Chapter 2 will provide a definition of financial derivatives (and of the variety of financial derivatives contracts), an assessment of the costs and benefits of derivatives, and an overview of the features of derivatives markets. Chapter 3 will discuss the importance of financial stability and the emergence of macro-prudential regulation, especially in relation to the Great Financial Crisis and to the role that financial derivatives played in the origin of the 2007-08 crises and its following trajectory. Chapter 4, then, will present the principles of financial regulation and assess the weaknesses and limitations of the present system of financial regulation, before discussing the measures that have been taken to regulate OTC derivatives in particular. The chapter ends with a discussion of CCPs and the issues that arise about the capacity of these institutions to protect the financial system from sources of systemic risk.

The methodology followed in the present study is illustrated in Chapter 5, which introduces the simulation method in general and the features of agent-based modeling in particular, with particular reference to the use of the technique in economics, finance, and derivatives market research. Chapter 6, then, presents the design and implementation of the model of financial derivatives industry, that is developed in the Netlogo language. Chapter 7 presents the results from the simulation of the model, both in the variants without (Model A) and with (Model B) the presence of CCPs, and contrasts and compares the results obtained from the simulation. Finally, Chapter 8 presents the conclusions of the study.

Chapter 2

Derivatives and Derivatives Markets

2.1 What are Derivatives?

Within the field of finance, the term ‘derivative’ has not a unique meaning. A general definition of derivatives is ‘financial arrangements whose returns are linked to, or derived from, changes in the value of stocks, bonds, commodities, currencies, interest rates, stock indexes or other assets’ (Acharya et al., 2009; Cohen, 1994; Faubus, 2010; Lynch, 2011). As such, a derivative is a category of financial contracts that encompasses a wide range of instruments, such as traditional securities (e.g., derivative futures of corporate, municipal and mortgage bonds), exchange-traded instruments (e.g., options and futures with standardized contracts in relation to size, maturity and delivery), and so-called ‘over-the-counter’ (OTC) instruments (i.e., contracts that are negotiated privately and that are typically customized to meet specific needs of counterparts). While each of these types of derivatives has special features, all derivatives share some common traits. All derivatives, in particular, are written and agreed by counterparts for arranging a risk-shifting transaction, i.e., one party agrees, upon receipt of a fee, to take on the risk of potential loss of the other party when a specified event materializes, especially in the relation to the value of another (‘underlying’ or ‘reference’) asset (Awrey, 2010; D’Souza et al., 2009; Samuel, 2009). As we shall review below, this common trait of derivatives makes them a valuable component part of nowadays’ financial industry.

The way derivative contracts are structured makes them akin to a ‘quasi-guarantee’ or ‘quasi-insurance’ contract (Lynch, 2011). Via derivatives, some parties can shift risk to other parties by making them enter into certain transactions - or by exiting certain transactions - so that losses are charged on the counterparts. These features of derivatives make them functional to assist economic agents (i.e., business companies, investors, financial intermediaries, etc.) to partially ‘shield’ themselves from the losses that they would incur if any risky event happens: one party of the derivative contract can ‘hedge’ themselves by paying the counterpart to carry part of the risk related to an investment

position. As a matter of fact, however, these features of derivatives also make this kind of contract functional to placing ‘bets’ on the direction of change of values of the underlying assets: indeed, derivatives may be written and traded without any need to actually ‘own’ the underlying asset (Baker, 2009; Lynch, 2011).

Derivative contracts come in several formats (Minehan and Simons, 1995). Before discussing the role of derivatives in nowadays’ financial industry (and, relatedly, the regulation of derivatives), we briefly review the main types of derivative contracts. These include four main categories, namely forward, futures, options, and swaps (Samuel, 2009). In addition, derivative contracts can be distinguished into two classes, depending on whether they are traded via specialized derivatives markets or not (i.e., OTC derivatives). Moreover, derivatives can be distinguished depending on the kind of underlying asset (e.g., commodities, equity, bonds, interest rates, credits, and foreign currencies), although generally options are related to stocks, forwards and futures to commodities, and swaps to debts (and interest rates) (Samuel, 2009). Taking into account the variety of derivatives, and also how versatile these financial instruments are to service particular needs or aims of the counterparts, it should not come as a surprise that derivatives constitute the highest growing segment of the financial industry in the last a few decades (Minehan and Simons, 1995). Indeed, since the early surveys of the derivative market (e.g., Kambhu et al., 1996) it became apparent that writing and trading of derivatives were set to grow all over the industrialized world.

Forwards: A forward contract is ‘an agreement between two parties to buy or sell an asset at a specified future time, referred to as the delivery date, for a specified price’ (Romano, 1996). The forward contract creates the obligation for the buyer (who assumes a ‘long position’) to acquire the underlying asset from the seller (who assumes a ‘short position’) at a certain future date and at a certain agreed-upon price. As such, the forward contract removes the risk of fluctuation of the asset price for both parties, who are certain about the price of the transaction at the future date. If parties had to make the transaction at the future date without the possibility of the forward contract, then they would now know the price in the future spot market until the future date. The forward contract, then, is valuable because it provides the parties the certainty that the transaction occurs at a given price. Of course, while both parties have the benefit of price certainty, if the price of the underlying asset fluctuates over time then the forward price may be more advantageous to one party than the

other one: for example, if the price of the underlying asset is higher than the forward contract price at the expiration date, then the buyer party gains from purchasing at a forward contract price that is lower than the market price while the seller party loses from giving away the underlying asset at a price that is lower than the market price; at the opposite, if the price of the underlying asset is lower than the forward contract price at the expiration date, then it is the seller party that gains from the sale of the underlying asset at a forward contract price that is higher than the market price while the buyer party loses from having to acquire the underlying asset at a price that is higher than the market price. At expiration, then, the value of the forward contract is the difference between the forward contract price and the market (spot) price of the underlying asset.

Futures: A future contract is a standardized form of forward contract (Romano, 1996). The future contract contains the obligation for one party to buy or sell an asset at a specified future date and for an agreed-upon price. Differently from forwards, that can be designed on an ad hoc basis depending on the aims of the parties, future contracts include conventional provisions that make them relatively easy to transfer in publicly organized market (exchanges). Future contracts are written on a variety of underlying assets, such as physical commodities (e.g., agriculture, natural resources, precious metal, etc.) and financial assets (e.g., equity, interest rates, bonds, foreign currencies, etc.). As in the forwards, future contracts arise from parties' intention to reduce risk about the future price of the underlying asset. While the market price of the underlying assets fluctuates, the parties can use the future to agree upon the price of the transaction at a future date. As such, when future contracts are written the parties make use of the best available information about price tendencies of the underlying asset, with the effect that the strike price of the future contract and the market price of the underlying asset tend to coincide on the expiration date (else, there is an opportunity for arbitrage). Along the process, futures play an important role as 'price-discovery' mechanism for the spot price of the underlying asset (Minehan and Simons, 1995), because parties who possess new information about the value of the underlying asset would enter the future market and disclose their information along their trading behavior.

Options: An option contract is an agreement that grants to a party the right to buy (*call option*) or to sell (*put option*) an asset at a specified price (*exercise or strike price*) on or before a specified future date (*expiry date*) (Romano, 1996). More precisely, an option is

structured as an *American* option if the party can exercise the right to buy or to sell at any time by the expiry date, while it is structured as an *European* option if the party can exercise the right to buy or to sell at the expiry date only. As in futures, in option contracts parties agree to reallocate the risk that the price of the underlying asset fluctuates in the future. In particular, the buyer of a call option exercises the right to buy the underlying asset if the price of the asset raises above the strike price, while the buyer of a put option would sell the underlying asset if the price of the asset falls under the strike price. Differently from forwards and futures, options include the attribution of rights to the buyer - not of obligations - to make a transaction at an agreed-upon price. The owner of an option, therefore, pays for the option a value (*option premium*) that relates to the estimation of the gain that the party would make if the right (to buy or to sell) is exercised and of the likelihood that the scenario where the exercise of the option is advantageous materializes (i.e., that the price of the underlying asset raises above the strike price in a call option or that the price of the underlying asset falls under the strike price in the put option). The seller of the option (*option's writer*), instead, is obliged to perform, i.e., to sell the asset if the call option is exercised or to buy the asset if the put option is exercised. Consequently, the prospects for gain and loss for the buyer and seller of an option contract are asymmetrical: the premium payment is both the maximum loss for the buyer of the option and the maximum gain for the writer of the option; the buyer can gain the (theoretically unlimited) difference between the asset value at the time of exercise and the strike price in a call option, or the difference between the strike price and the asset value at the time of exercise in a put option; the seller can lose the (theoretically unlimited) difference between the asset value at the time of exercise and the strike price in a call option, or the difference between the strike price and the asset value at the time of exercise in a put option. Because of this payoff structure, the value of an option is generally dependent on the volatility of the underlying asset, i.e., the gain for the buyer of the option is higher, the higher is the asset value with respect to the strike price at the time of exercise in a call option, or the lower is the asset value with respect to the strike price at the time of exercise in a put option.

Swaps: A swap contract is an agreement between two parties to exchange a series of cash flows, based on the underlying value of an asset, over time (Romano, 1996). Generally, swaps are written on underlying assets such as foreign currencies, interest rates, commodities, equity, or other financial instruments. A relatively simple swap, for instance, is the 'plain vanilla' interest rate swap, where one party agrees to make a fixed-rate

payment to the counterpart, who agrees to make a floating-rate payment in return. In practice, rather than each party paying its respective payment, only the net difference between the two cash flows is paid by one party to the other. A swap contract like this one, in all effects, provides a reallocation of risk from one party to the other one: depending on the relative value of the agreed-upon fixed interest rate and of the floating interest rate, it is one party that provides a flow of payment to the other one or the other way round. A related way to reallocate risk is the one provided by combinations of swap and options contracts, i.e., *swaptions*, where the buyer is given the right to enter into a swap contract at a later date, or to terminate or extend an existing swap contract at a later date. For example, an interest rate swap can be combined with an option to form so-called *caps* or *floors* contracts, that provide the owner the possibility to set a maximum or minimum interest rate payment for the floating side of the swap contract. A cap and a floor contract, moreover, can be combined into a *collar* contract, that provides the possibility for the owner to keep the floating of an interest rate-related flow of payments within an agreed-upon volatility range (i.e., the buyer of a cap contract can also sell a floor contract in order to make the net premium more affordable or nil). Swap contracts are typically customized (i.e., they are made 'ad hoc' for the particular aims of the counterparts) and therefore they are not traded on exchanges.

Not every type of derivative can be traded in derivative exchanges. Derivatives markets - such as the Chicago Board of Trade (CBOT) - tend to include only those types of derivative contracts that can be standardized, i.e., whose contractual terms are specified in conventional provisions and clauses, so that derivatives of the same type can be indifferently traded among financial and economic operators. Futures and options are the two types of derivatives contracts that are typically traded in regulated exchanges, where intermediary operators (*market-makers*) provide the market infrastructure needed for hosting the activity of buyers and sellers. Those derivatives whose contractual terms are customized, i.e., designed ad hoc depending on the needs and aims of the counterparts, are agreed upon by the parties and they are not typically traded in exchanges. Customized derivatives - generally called *over the counter* or OTC - include forwards, swaps, and various types of option contracts whose contractual terms are specifically tailored to the particular agreement between the counterparts. As OTC derivatives are not traded in exchanges, they are not subjected to the same reporting, standardization, and margin requirements as exchange-traded derivatives (D'Souza et al., 2009).

Among the OTC derivatives, those that relate to underlying credit assets deserve some particular attention, especially because of the role that they played in the 2007-2008 financial crisis. Generally, *credit derivatives* consist of a particular type of derivative contract where the underlying asset is a credit (Faubus, 2010; Lynch, 2011). In this kind of derivatives, the quality of credit is pivotal: depending on credit quality, credit risk - that is, generally understood as the probability of default of an outstanding obligation - affects the market value of the underlying debt. Various types of credit derivatives exist, while most of them consist of credit default swaps, total return swaps, credit linked notes and collateralized debt obligations. In all these types of credit derivatives, one party (the 'protection seller') provides some sort of guarantee or coverage of losses related to the underlying credit to the other party (the 'protection buyer').

A ***credit default swap*** (CDS) is a contract where the protection buyer pays a premium (called CDS spread) to the protection seller for being compensated for any loss resulting from a credit event incurred by the reference entity. For example, a CDS may be bought by a corporate or sovereign bond holder and sold by an insurance company, which would compensate the loss that the buyer of the CDS incurs if the reference entity - a business company or a government - defaults its debt. A CDS can reference a particular debt security (e.g., a bond) or a portfolio of debt securities.

A ***total return swap*** is a contract where the protection buyer rents out an asset to the protection seller. The protection seller pays a stream of regular payments, while the protection buyer transfers income and capital changes from the reference asset to the protection seller. The protection seller takes all the gains and losses incurred by the asset, that remains in the ownership (and balance sheet) of the protection buyer. While the CDS provides that the protection seller makes a payment to the protection buyer just in case of default of the underlying debt, in the total return swap the protection seller agrees to make the flow of payments to the protection buyer regardless of the performance of the underlying credit.

A ***credit linked note*** is a contract where the protection seller raises capital from investors with the purpose of providing credit protection to the protection buyer. Typically, the operation entails the creation of a special-purpose vehicle (SPV) or entity that acts as the

protection seller. The buyer pays a premium to the seller, which then uses part of this money to pay investors for their funds. In principle, the scheme allows to remove the entire credit default risk because the money is raised for the sole purpose of protecting the credit of the protection buyer.

Finally, a *collateralized debt obligation* (CDO) is a financial product that pools together various cash-generating assets (e.g., debt obligations) and repackages them together into different tranches of assets that are then sold to investors. The scheme is typically implemented through SPVs, that raise money for buying the cash-generating assets by offering various tranches with different levels of risk-and-return profiles. Most senior tranches have relatively lower returns and risks, while equity tranches (that typically provide relatively small amounts of capital) have highest return expectation and risk. The SPV earns the difference in the spread between the return for the investments and the aggregate amount of returns that are paid to the various tranches.

Although OTC derivatives are not traded in exchanges, nevertheless an institutional infrastructure is typically needed to assist the negotiation and legal definition of the terms of OTC derivative contracts. At least two scenarios are possible. In a fully decentralized market, participants negotiate, write, trade and settle their positions directly with one another. In a more structured interaction, participants negotiate, write, and trade OTC derivatives in a decentralized fashion, but the market is provided with an agent - called Central Counterparty Clearing House (CCP) - that assists the clearing of the derivative positions. The kind of institutional organization of the OTC derivative market has important consequences for the risks and for the techniques employed to deal with it.

In a fully decentralized market, participants manage counterparty risk through contractual arrangements that include collaterals and bilateral netting. Collaterals relate to the requirement to daily post collaterals that reflect the mark to market changes in the value of the contracts. Bilateral netting relates to agreements for netting across different contract types. Bilateral netting significantly reduces the amount of credit exposure, so that also the amount of collaterals needed is consequently decreased. Such decentralized market provides participants with a flexible way to tailor OTC derivative products to their needs, although a large amount of such derivatives may consist of *de facto* relatively standardized contracts. However, fully decentralized markets are not very transparent, as participants

tend not to disclose derivative prices (especially, market-makers that play the role of intermediaries and that can profit from price discrimination among their customers). The presence of the CCP helps reducing information asymmetry, and it provides lower counterparty credit risk as every participant is exposed to the credit risk of the CCP (Baker, 2009).

It should also be remarked that credit derivatives can be settled in two ways. In the *physical settlement*, the occurrence of a credit event (e.g., default of the debtor) entails that the protection buyer has to deliver to the protection seller the underlying reference obligation, in exchange for the strike price of the reference obligation. In the *cash settlement*, instead, the protection buyer does not have to deliver the underlying reference obligation, but the protection seller just pays the buyer the net loss that results from the credit event. In other words, the contract is settled by *netting* the positions of the parties.

2.2 The Benefits of Derivatives

Derivatives have been used in commercial activities since early recorded history. Forms of option contracts, for example, were already used by the Phoenicians and the Romans in relation to the delivery of goods transported by ship (Romano, 1996). More recently, future contracts were written on tulip bulbs in the Netherlands and derivatives were well established means of commercial activity in the Dojima rice futures markets in the 18th century in Japan (Acharya et al., 2009). In the modern era, the use of financial derivatives took off in the 1970s, especially in relation to various financial, economic, and policy conditions in the main industrialized countries. The time was characterized by the end of the Bretton Woods system, which resulted in greater uncertainty about currency fluctuations and increased volatility of interest rates. In order to hedge against interest rate risk, mortgage companies, such as GNMA (Government National Mortgage Association, a US corporation owned by U.S. Department of Housing and Urban Development, also known as ‘Ginnie Mae’) started making use of future and swap contracts. Since then, derivatives have been increasingly used by both business and financial operators, either in regulated markets (such as the Chicago Board of Trade, founded in 1848, the Chicago Mercantile Exchange, founded in 1989, and the London International Financial Futures Exchange, founded in 1982) or through OTC ‘bespoke’ contracts (especially, Credit Default Swaps since the 1990s).

Nowadays, derivatives constitute a large part of financial markets, at least in relation to their nominal value. The most recent estimate of the notional amount of futures in the world, in June 2014, is US\$ 29 trillion and of options is US\$ 44 trillion¹. The most recent estimate of the notional amount of outstanding contracts of OTC derivatives, at the end of June 2014, is US\$ 691 trillion². The supply side of the industry is relatively concentrated, especially around five main US institutions - JPMorgan, Goldman Sachs, Bank of America, Morgan Stanley and Citigroup - and a few European ones - Barclays, BNP Paribas, Credit Suisse, and Deutsche Bank. The demand side, instead, is populated by several actors, especially including investors, commercial banks, and business companies (as surveyed by such sources as, for instance, the BIS Semiannual Derivative Statistics, Fitch Ratings, and Standard and Poor's; Gibson, 2007).

Why do derivatives exist? We may argue that, if derivatives exist, then they must result in some form of advantage for the parties that enter the transaction. In an ideal world, where there are no trading costs, no transaction costs, no taxes and no regulations, and where every actors could borrow at the same risk less interest rater, derivatives would not be needed to perform any economic function (Minehan and Simons, 1995). They play a role in the economy, instead, exactly because of the presence of 'market imperfections' that open up the possibility to create value by reducing trending costs, or transaction costs, or taxes, or the regulatory burden. In the experienced world, derivatives play a role because they essentially reallocate risk. Derivative contracts enable to isolate a particular kind of risk and to shift it from one party to another (Awrey, 2010).

Derivatives can help reallocating risks in several ways. Some derivatives, for example, help reducing the risk of foreign currency fluctuations, thereby assisting the development of international trade (Cohen, 1994). Other derivatives help reducing the risk of interest rate fluctuations. Other derivative contracts - options - allow the risk protection buyer to hedge against particular risks (for example, a protective put strategy enables an investor to protect from the risk of a decline of a stock price). Swaps permit companies to hedge against interest rate risk (for example, by swapping a floating rate debt into a fixed rate one). Credit derivatives assist financial operators to reduce risk from ownership of bonds or loans, to take risk exposure towards another entity, and to express a credit view on other entities

¹ BIS web site, http://www.bis.org/statistics/r_qa1409_hanx23a.pdf, accessed 21st November 2014.

² BIS web site, http://www.bis.org/publ/otc_hy1411.htm, accessed 21st November 2014.

(Lynch, 2011); they also allow to separate the function to originate credit (typically, to corporate borrowers) from the one of holding credit risks associated with the loans (Hirtle, 2009).

The use of derivatives also entails various beneficial effects to other economic actors and to the economic system more generally. Derivatives, for example, help the working of the market system by assisting the ‘price discovery’ mechanism (Hentschel and Smith, 1996; Minehan and Simons, 1995). Generally, markets are affected by the presence of information asymmetries between parties, where one party that is better informed seeks to gain over the other who holds inferior information (Bagehot, 1971). When there are large information differences, typically bid-ask spreads are higher. Derivative markets attract traders who possess superior information because gains can be amplified through leverage. Therefore, fewer traders operate in the market for the underlying assets, and this market becomes more efficient. The prices of the underlying asset and of the derivative are linked because of arbitrage opportunities, in a way that the information in the derivatives market affects the prices of the underlying assets (a so-called ‘migration of information’ that reduces the spread and increases the volume of trading; Damodaran and Subrahmanyam 1992). Derivatives also help enhance liquidity in markets, especially because trade in the derivative market is relatively cheaper than in the underlying asset one.

Some special considerations should be made, in particular, on the role and benefits of OTC derivatives. Differently from the standardized derivatives traded on exchanges, OTC derivatives enable customized solutions to issues of risk management (Backer, 2009). According to Awrey (2010), OTC derivatives contribute to the working of economic systems in three ways:

Completing asset markets: If derivatives do not exist, then economic actors would hold the whole risk that is associated with any portfolio of ownership of assets, i.e., they would hold market risk, lender credit risk, foreign exchange risk, and so on. With OTC derivatives, instead, economic actors have various flexible ways to ‘unbundle’ risk related to their particular financial and business conditions. By using OTC derivatives, economic actors can restructure the risk in a tailored way that fits with their risk preferences in a way that would be otherwise impossible or too costly to attain without them.

Enhancing price discovery: If derivatives do not exist, then buyers and sellers of an asset (or goods) would spend some time to negotiate and explore the range of potential price agreements. In principle, the discovery of the equilibrium price in a market may take advantage of arbitrage, where economic actors exploit information asymmetries between preferences of buyers and sellers for their advantage. Yet, arbitrage in the market for assets (or goods) is relatively expensive. With OTC derivatives, instead, economic actors can engage in the arbitrage of assets for even relatively small price deviations because of the possibility to trade the OTC derivatives rather than the underlying assets.

Absorbing systemic risk: If derivatives do not exist, then financial institutions that hold large risk towards several other counterparts may originate a concatenation of losses if the risk event takes place. With OTC derivatives, instead, financial institutions can shift risks to other parties that are more willing and capable to absorb them. As a result, if economic actors make use of derivatives then the market is more stable and resilient: any materialization of the risk event (e.g., a default), in fact, would not pose a serious risk of additional defaults among other economic actors.

The use of OTC derivatives also results in additional benefits (Backer, 2009), that include: the possibility for business firms to hedge their financial and business risk; the increase of liquidity in underlying markets; the possibility to diversify investment portfolios; the improvement of accuracy of market prices (e.g., CDS spreads provide signals on specific credit risk); the diversification of risk in a way that is broader than the one usually attained with more traditional financial instruments; the increase of bank credit capacity, that results in additional lending; more flexibility in counterpart credit arrangement than exchange trading (with beneficial effects, for instance, on the management of working capital); finally, derivatives allow to complete financial markets by enabling trading of risk by itself rather than assets.

To be fair, the praise for derivatives ought to be weighted against allegations that these financial instruments - especially, some kinds like CDS - result in *enhanced* rather than reduced risk. Indications from the 2007-08 'great financial crisis', indeed, fueled the arguments against the use of OTC derivatives. Various authors, however, hold that the benefits of derivatives generally outweigh their presumed pitfalls. Acharya et al. (2009), for instance, argue that the use of OTC derivatives allowed the spreading of credit risk across

several global investors and away from capital constrained financial institutions, with the resulting effect of expanded credit available to individuals and firms. In addition, they hold that CDS and other derivatives have actually contributed to contain the consequences of the source of the crisis, especially by disseminating information about credit risk to regulators and the public. While the securities markets may have not properly assessed the value of stocks, bonds, and other financial instruments, the CDS market was able to provide signals about the quality of financial institutions' bankruptcy prospects.

The widespread use of CDS and other credit derivatives, indeed, suggests that economic actors may benefit from these financial instruments in several ways. Commercial banks tend to use credit derivatives to adjust their credit risk exposure (Gibson, 2007): they may use, for example, single-name CDS (i.e., CDS that are specifically tailored to hedge from credit risk of a particular operator) to shield themselves from the credit risk of issuers of securities to whom they have a large exposure. Investment banks tend to use credit derivatives to deal with the risk that they hold when they underwrite securities: for example, the investment bank assumes credit risk for the short time between when it takes the risk on a security (e.g., a residential mortgage backed security) and when it sells the risk to the market, which takes place when the investment bank can assemble a large amount of contracts to launch a securitization. Finally, investors tend to use credit derivatives to align its credit risk exposure with its desired credit risk profile: in fact, credit derivatives can be more flexible and less expensive than transacting in the underlying securities.

The use of derivatives, therefore, also fundamentally depends on the aims of the economic actors. Some investors like pension funds, for example, may be interested in a 'buy and hold' strategy, that consists of earning from the return of fixed income securities. Other investors like hedge funds, instead, may pursue an 'active trader' strategy, that consists of earning a return by predicting short-term price movements better than other market participants. Whatever the investment or trading strategy of the economic actors, however, the use of derivatives results in a more efficient management of the financial portfolio. If investors do not use derivatives, then they can only rebalance their portfolios (in relation to changed expectations of future return and risk performance) by buying or selling securities, such as stocks or bonds. Some of the securities markets, however, may be illiquid, therefore the investors may incur high transaction costs. Even if the investors seek newly issued securities, the price may be influenced by particular contingencies in the market at that

time, which can make the adjustment of the portfolio not advantageous. If the investors can use derivatives, instead, then they can adjust the risk profile of their portfolios by hedging against the unwelcome events, e.g., by purchasing risk protection against credit defaults using CDS. The bid-ask spread on CDS, in fact, is generally lower than the bid-ask spread on underlying assets like corporate bonds.

Finally, we should also notice that the apparent benefit of using derivatives has been documented in various empirical studies. Research works showed that the use of derivatives reduces total risk and systematic risk for firms, and that there may be also a positive (albeit weak) effect on the value of firms (Allayannis and Weston, 2001; Bartram et al., 2011; Graham and Rogers, 2002; Guay and Kothari, 2003; Hentschel and Kothari, 2001; Jin and Jorion, 2006). Others highlight that the use of derivatives extends to more general benefits for the economy. Hirtle (2009), for example, found some evidence that the use of credit derivatives is associated with greater supply of bank credit for large term loans, in terms of longer loan maturity and lower spreads. Faubus (2010) remarked that, in the view of Alan Greenspan, the widespread use of CDS mitigated the potentially devastating repercussions of some among the largest corporate defaults in history, such as WorldCom and Enron) and the largest sovereign defaults in history (such as Argentina's in 2001).

2.3 The Costs and Risks of Derivatives

Derivatives have been often regarded as the source of various costs and risks, both to the performance of individual firms and of the economic system as a whole. Along this view, derivatives should be heavily regulated, or even banned, in order to prevent serious troubles to the economy. It is relevant, therefore, to review the arguments that are typically made for criticizing the use of derivatives in contemporary finance. Generally, these arguments primarily build on the view that derivatives entail moral hazard problems (Peek and Rosengren, 1997; Remolona et al., 1996), that is, one party of the derivative contract is inclined to behave irresponsibly exactly because of the protection against risk that is provided by the derivative contract itself. The problem is exemplified, for instance, by a risk protection buyer who may shrink to carefully monitor its credits after buying a credit derivative; or by a risk protection seller who may shift the risk to other entities (e.g., a subsidiary) or under-represent the risk exposure in the financial reports in order to attract

more credit derivative buyers. In these cases, the use of derivatives results in ‘perverse incentives’ for the counterparts to behave in a way that exacerbates their risk position.

Moral hazard, however, is not the only kind of problems that are typically associated with the use of derivatives. Cohen (1994), for example, noticed that derivatives may result in losses for those parties who do not adequately assess the likelihood of exposure to unwelcome future events, as it may be the case for unsophisticated investors who do not really understand and anticipate the economic, financial and legal effects of derivative contracts. Derivative contracts are also fundamentally subjected to counterpart risk, i.e., the possibility that the other side of the contractual relationship does not fulfill its obligations because of insolvency. Also, derivatives may not be cautiously managed if parties lack appropriate internal control mechanisms, or they lack operational capacity to book and monitor transactions and update estimates on potential losses. In addition, derivatives contracts may be occasionally difficult to enforce, especially when dealing with foreign counterparts. Sometimes, derivatives may be impossible to enforce, if the market for the underlying asset becomes illiquid. There is also the possibility that derivatives do not deliver the expected risk protection because of political upheaval or natural catastrophes. Finally, derivatives also open up possibilities for various kinds of deliberate abuse and frauds, including misrepresentation of information towards counterparts and the general public.

Among the various kinds of derivatives, OTC ones pose special issues that especially originate from the complexity of these financial instruments (Duffie et al., 2010). According to Awrey (2010), OTC derivatives expose counterparts to four types of peculiar risks:

Risks arising from information asymmetry: OTC derivatives are designed on the basis of complex mathematical formulas, which build on sophisticated financial concepts, and which are articulated in complicated legal documentations. As such, any party of the derivative contract must possess highly specialized and advanced knowledge in order to understand the terms, conditions, and effects of the OTC derivative contracts. However, in practice individuals possess relatively limited information, time, and resources to cope with the cognitive load required to fully understand OTC derivatives. Often, the party that designs the OTC derivative contract (i.e., the financial institution that sells protection, or a

financial intermediary) possesses a more detailed understanding of the contract than the counterparts (e.g., a business company or a local government), especially in complex OTC derivatives such as CDO.

Risks arising from over-investment: OTC derivatives are typically used to shift risks away from one party, which can then exhibit a better financial outlook to clients and investors. As such, OTC derivatives result in greater capital available for investments, lower interest rates, minor credit spreads, and - ultimately - in the under-pricing of credit risk. The effect of OTC derivatives, therefore, may be the one to induce a sub-optimal excess of investments, as apparently was the case in the mounting up of the 2007-08 financial crises, when financial market conditions (that also related, however, to lax monetary policies, to the US-China trade imbalance, and to the growth of the so-called 'shadow' banking system) contributed to the US housing bubble that eventually resulted in widespread negative externalities after the adjustment of house prices.

Risks arising from excess leverage: OTC derivatives may also facilitate highly leveraged speculation, that is, to enable parties to take significant speculation risk while employing relatively little capital. This conduct may be harmful for the party taking too much risk, but it may be also detrimental for the financial system on the whole, if the party that assumed a too high risk position because of the leveraged OTC derivative contracts may negatively affect, in case of default, the solvency of other economic actors.

Risks of systemic sort: finally, OTC derivatives may be the source of systemic risks, i.e., the risk of a collapse of the entire financial system. This event may take place if the cost of OTC derivatives is not fully internalized by parties (i.e., by the risk protection sellers) but it spills over other economic actors, in a kind of 'snowball' or 'domino' effect. A possible scenario where this event can materialize is, for instance, when a small but critical mass of defaults result in the insolvency of additional financial institutions, which in turn throw other financial institutions into insolvency, and so on. Another possible scenario is related to conditions of illiquidity that can result in 'runs' that exacerbate the solvency position of financial institutions. In addition, additional sources of systemic risk arise from the inability to fully comprehend the complexity of nowadays' financial markets, and, relatedly, from the inadequacy of the pricing models that are commonly used in estimating risk exposures.

Among OTC derivatives, credit derivatives pose some even more particular issues on their own. Gibson (2007) highlighted that credit derivatives provide transformation of credit risk in very intricate ways, that are much harder to understand than more ‘ordinary’ risk shifting schemes. In addition, credit derivatives are especially sensitive to counterparty credit risk, which calls for enhanced efforts to closely monitor and assess credit risk positions. Also, the assessment of credit risk is essentially done through risk estimation models that may contain fundamental flaws or employ controversial assumptions. In part, the issue of assessing credit derivatives is tackled through the service provided by rating agencies, but the ratings can be misunderstood and therefore induce misinformed judgments. Also, additional issues arise in the settlement of a credit derivative contract following a default.

The issues that relate to credit derivatives in general are especially relevant in the management of CDS:

Credit risk: as any credit derivative, CDS enable to shift credit risk from one party to another. In case of default, the credit risk protection seller has to carry the loss that would have been incurred by the credit risk protection buyer. With CDS, however, the credit risk may be transferred through very intricate channels. If the CDS is of the ‘single-name’ sort (i.e., the credit risk protection is related to the default event of a particular security, e.g., a corporate bond) or of an ‘index’ sort (i.e., the credit risk protection is related to a portfolio of securities), then tracking the credit risk transfer is relatively straightforward. If the CDS is of a securitized sort, such as in the case of CDO tranches, then the structure of credit risk transfer arrangements can be relatively difficult to understand.

Counterparty risk: as any credit derivative, CDS entail the risk that the counterparty does not fulfill the obligations. In principle, counterparty risk may be partially tackled by acquiring more detailed information about the financial and risk position of the risk protection seller. In practice, however, it may be difficult to accurately assess exposure to future losses and counterparty risk is often mitigated through collaterals or margin requirements.

Model risk: some CDS, like the CDS indexes, are traded in liquid and transparent exchanges, and therefore their value is generally reflected in market prices. Other CDS, instead, are not traded in exchanges, and therefore their value is typically estimated through appropriate financial models. The evaluation method (‘mark-to-market’), however, builds

on particular assumptions that may not necessarily hold as valid in actual financial market dynamics. If this is the case, then the models are flawed and consequently the parties may lack any reliable information for pricing the CDS.

Rating agency risk: rating agencies play an important role in providing assessment of credit risk quality of derivative products. Although rating agencies may provide transparent details about the models that they use to assess derivatives, nevertheless they may base their assessment on flawed models or incomplete information. In addition, the ‘signal’ that they provide to market operators (i.e., the credit rating) should be carefully pondered, provided that the complexity of CDS entails that the risk associated with these financial instruments cannot be fully conveyed by the standards credit rating scale used for more traditional securities (e.g., bonds).

Settlement risk: finally, additional sources of risk related to CDS arise from the difficulties that originate from the settlement of the contract. Traditionally, credit derivatives are settled with the physical delivery of the referenced security in exchange for par (i.e., when the default event happens, the credit protection buyer transfers the referenced security - such as, for instance, a corporate bond - to the credit protection seller, who provides the agreed protection payment). It may happen, however, that the credit protection buyer does not hold the referenced security and therefore it needs to buy it from the market. On some market occasions, there may be scarcity of securities to settle the derivative positions. If this is the case, then the CDS may not be settled, or the price of CDS may be affected by the liquidity issue.

It should be highlighted that the issues that arise with derivatives are especially confined to OTC ones. Standardized derivatives that are traded in exchanges are typically evaluated in relation to market prices, and settlement of the contracts is typically assisted by the presence of a clearing house. The clearing house system of exchanges seems to work fairly well, provided that - since the origin of derivative trading in the modern era (the Chicago Board of Trade in 1848) there has not been any bankruptcy of clearing corporations, despite occasional attempts to corner the derivatives markets (Acharya et al., 2009). OTC derivatives, instead, cannot benefit from the presence of a clearing house. OTC derivatives are typically designed to serve particular financial and economic needs, and - in addition - they are often kept private. Accordingly, there is no central entity - clearing house or

regulator - who knows how many OTC derivatives have been written, where they are concentrated, what is the total exposure, and the total value of these contracts. The lack of transparency of OTC derivatives, therefore, is at the very core of much of the issues that arise in relation to these contracts.

It should be highlighted, moreover, that even the same phrase ‘market for OTC derivatives’ may be misleading, as it suggests the presence of a fairly well structured infrastructure for the trading of these contracts. Derivatives markets are typically distinguished into ‘primary market’ (that relates to the original writing of a contract between two counterparts) and ‘secondary market’ (that relates to the trading of one side of a derivative contract, typically in regulated exchanges). The so-called ‘market for OTC derivatives’ consists of a fairly concentrated network of contractual relationships between counterparts who write original contracts, while relatively ‘trading’ of existing OTC contracts takes place. As Awrey (2010) put it, “In reality, these [OTC] markets consist of little more than a closely-knit network of dealers who collectively perform both an intermediary and market-making function. As privately negotiated contracts, the identities of OTC derivative end-users, their positions, pricing and other transaction details are not readily available within the marketplace. Within such an environment, dealers thus often represent the only source of derivatives-related expertise and market information available to end-users.” As the parties of OTC derivatives may remain typically anonymous, it is difficult to know the web of mutual dependencies that is created by multiple contractual relationships (Baker, 2009).

These features of OTC derivatives make these contracts pose a salient threat to the stability of the financial system. As it will be discussed in next Chapter, the stability of the financial system is a common (or public) good that may be fundamentally undermined by the materialization of systemic risk. Lack of diffuse and reliable information about the credit risk position of financial institutions can be a source of systemic risk. If economic actors do not know ‘how much risk’ the counterpart has (already) assumed, then they are not in the position to fairly assess the price and likelihood that the risk protection can be effectively provided. If economic actors under-estimate the potential losses that arise from counterpart risk, then they may end up taking too much risk and find their credit protection vanished. If economic actors over-estimate the potential losses, instead, they may trigger a ‘run’ that eventually stimulates, or accelerates the default of the counterpart (i.e., a case of ‘self-fulfilling prophecy’).

2.4 The Market of Derivatives

The market of derivatives is typically populated by three kinds of economic actors, who respectively pursue hedging, speculation, and arbitrage (Baker, 20109; Samuel, 2009). Understanding the motives that drive these three kinds of economic actors is important in order to figure out the resulting effects of their interaction on the dynamics of the derivative markets. In principle, like any market also the derivative one results in the efficient allocation of resources if competitive prices inform the choices of rational economic actors. In practice, however, the derivative market is characterized by relatively few dealers on the supply side (e.g., credit protection sellers), relatively tight economic and social network connections, and information ‘overloads’ that put the limited cognitive resources of individuals under pressure. As a result, the efficiency of derivative markets is often put into question. If we also take into account that weak institutions may open up opportunities for moral hazard, then both market operators and policy-makers should be concerned with sustaining the credibility and trust towards derivative markets in order to ensure their continued operation.

The conduct of economic actors that pursue hedging, speculation, and arbitrage is analytically distinguishable. Hedging is a risk management practice that enables economic operators to ‘shield’ themselves from unwelcome future events (e.g., a drop or surge in market prices) that can result in losses. Speculation is a gamble that economic actors take in consideration of the possibility to make a profit in exchange for the willingness to assume a risk of loss, depending on the materialization of a future event. Arbitrage is a profit-making practice that consists of exploiting differences in prices for the same asset between two unconnected markets, or market segments, or market participants. Needless to say, arbitrage plays an important role in the working of efficient markets: it is exactly because of the presence of smart and well-informed economic actors that one price only exists in the market for any asset. If arbitrage operators realize that, for example, two market participants are willing to trade the same asset for two different prices respectively, then the arbitrage operator can promptly purchase the asset from the participant who is willing to sell it at a low price and to sell the same asset to the participant who is willing to buy it at a high price, while making a ‘risk-free’ profit out of the two trades.

While the kind of trade activity done by speculation and arbitrage operators is occasionally condemned in moral arguments, they both contribute to the effective and efficient working of the market mechanism. As a matter of fact, the same hedging behavior may not exist if the market is not populated by operators that pursue speculative purposes. When an economic actor aims to hedge against a risk, another market participant should be able to take on the risk. If all market participants share the same economic interest and risk concerns (e.g., farmers who intend to shield from the risk of future price decrease), then they would not find counterparts. In order for the shift of risk to take place, then, some market participants must have an economic interest to take on the risk by placing a ‘bet’ that the unwelcome event will not take place. The presence of speculators, therefore, provides the counterparts to those who aim to hedge against particular risks (Romano, 1996). In principle, speculators may place their ‘bets’ by purchasing (or selling) the underlying assets or commodities before the expected increase (or decrease) of price takes place. In practice, instead, speculators find it more efficient to operate on derivatives market (rather than on the markets of underlying assets or commodities) because less money is needed to enter derivatives contracts than trading assets or commodities, or because the assets or commodities may not be available to buy (or sell) at the preferred time.

As already highlighted, the complexity of contemporary derivative products results in a deeply interconnected pattern of relationship between market operators. The securitization of credit derivatives resulted in complex financial products, such as CDO, that only a narrow group of specialists could deeply understand. With the introduction of CDS, credit risk was transferred from one financial institution to another in ways that became uncharted by both market participants and regulatory agencies. Within such environment, it is sometimes difficult to discern whether an economic actor pursues a hedging strategy, rather than speculative or arbitrage purposes. As a matter of fact, the differences between the aims of economic actors may be more a matter of analysis than actual conduct: the same market participant, in fact, may both employ a CDS to hedge its own risk profile while, at the same time, enter CDS contracts to speculate on selling protection to another market operator.

What is the effect of such complexity on dynamics and performance of derivative markets, and on the financial system more generally? Credit derivatives (especially, CDS) can serve the role of the proverbial ‘canary in the coal mine’: if the price for CDS reflects the best information available to market participants, then the widening and volatility of spreads

should convey market signals about the increased credit risk position of any referenced security and market participants can adjust their portfolio accordingly. On the other hand, credit derivatives can trigger abrupt portfolio adjustments: if market participants over-react to the widening and volatility of spreads (which may originate from real issues), then CDS may contribute escalating relatively minor price fluctuations into widespread widening and volatility of spreads (which can have price and liquidity consequences on the market for the underlying asset, in turn). The resulting effect of CDS (as well as other OTC derivatives), therefore, is apparently the one of inducing sources of *instability* into the derivatives market, as well as potentially in the overall financial system.

As a way to clarify how the derivatives market work, let us briefly recall the main features of financial markets generally. Financial markets are organized platforms where economic actors engage in negotiations and trading of securities. In contemporary financial markets, transactions are assisted by computerized systems that compute the matching between buying and selling orders. In addition, the financial market organization provides public information about prices (traded prices, bid prices and ask prices) and other statistics (e.g., volume). The working of the financial market, moreover, is typically coordinated through some kind of price discovery mechanism, that typically consists of a ‘double auction’ system (Cason and Friedman, 1996). This market platform is operated by different kinds of participants, that differ in relation to their role in the price discovery and market matching process:

Investors (or clients): the participants who enter the market to attain hedging, speculation, or arbitrage aims.

Brokers: market participants who connect the buyers and the sellers for a concession or fee, without taking any risk on the transaction.

Dealers: market participants who provide and commit to a quote if a client requests, or have to take the opposite side of an order if the order is executed. Dealers make use of their own capital to cover from losses and keep liquidity.

Market-makers: market participants who are required to post both bid and ask prices for the securities that they are expected to trade in. If another market participant wants to buy

or sell at the prices provided by the market-maker, then the order must be executed. If the market-maker cannot find a corresponding seller or buyer, then it must execute the order in person.

As a matter of fact, financial markets work with clients and brokers placing orders to dealers and market-makers who take note of the order positions and temporarily 'hold the bag' while they search for corresponding clients and brokers who can act as counterparts to the transactions. In exchanges nowadays, the search for matching counterparts takes place by stimulating competition on both the buying and selling sides (i.e., both bid and ask prices are surveyed and a settlement point is reached when the highest buy price meets or exceeds the lowest sell price). If the market is liquid (i.e., there relatively many buyers and sellers operating continuously and that are readily available to match an order), then dealers and market-makers do not need to hold any position too long (and they can profit from the bid/ask spread).

Derivatives markets - especially, the markets of standardized derivatives - work along the same general principles of financial markets. With respect to the trading of underlying assets such as stocks or bonds, however, the trading in derivatives takes places in relatively more illiquid market conditions. One reason for the relative illiquidity of derivative market is that, for any underlying asset, there are a number of possible derivative contracts that are typically traded in exchanges, e.g., options that differ in terms of strike price, expiry dates, and terms of settlement. While liquidity in the market for the underlying asset may be high, the markets for the related derivatives are less populated. Because of this, occasionally bid/ask spreads may tend to diverge and the market price may exhibit relatively wide fluctuations.

The working of standardized derivative markets is facilitated by the infrastructure support provided by the exchange companies. In the US, for example, the Options Clearing Corporation (that originates from the Chicago Board Options Exchange Clearing Corporation established in 1973) provides central counterpart clearing and settlement services to 14 exchanges and to various kinds of securities, including options, financial and commodity futures, security futures and securities landings. In exchanges, where derivatives are standardized, market operations can take place on 'undifferentiated' or 'fungible' contracts, that help liquidity of the market. Standardization of derivatives also

help making ‘netting’ (i.e., the settling of multiple cash flows obligations with one net cash transfer only) possible also on the same derivative across different exchanges. As a matter of fact, however, it often happens that dealers and market-makers are not able to match buyers and sellers on precisely the same type of derivative and at the same time. While they ‘hold the bag’, therefore, they carry the risk that the counterpart shifted to them. As a way to partially offset the risk while searching for a match in the market, dealers and market-makers constantly adjust their market portfolio with the aim of hedge themselves (so-called ‘dynamic hedging’).

The working of ‘non-standardized’ derivatives markets - that is, markets of OTC derivatives - work in a quite different way. The trading of OTC derivatives consists of complex and detailed contracts between large investors (e.g., a business company) and dealers (e.g., a bank). The terms of OTC derivatives contracts are typically ‘exotic’ or ‘unusual’, in the sense that they carry unique conditions on strike price, expiry date, and so on. As such, any order to buy or sell OTC derivatives (including, of course, CDO and other credit derivatives) in a hypothetical market cannot be plausibly matched with any counterparts - provided that very idiosyncratic motives drive the investors and the dealers to write the OTC derivative. The ‘market’ of OTC derivatives, then, is actually confined to the contracts between investors and dealers. The dealers take on the risks from the investors, and then seek to hedge their risk position through a combination of other derivatives trading.

Chapter 3

Financial Stability, Systemic Risk, and Derivatives

3.1 What is Systemic Risk?

Systemic risk is a fundamental concept in our understanding of the structure and dynamics of the financial system. In general terms, systemic risk relates to the possibility that a chain of consequential behavior results in negative widespread effects to the whole financial system. Faubus (2010) defined it as “the risk that a ‘trigger event’ such as a market or institutional failure will cause a chain of consequences negatively affecting both market participants and the larger economy”. Acharya (2009) conceived it as “the endogenously chosen correlation of returns on assets held by banks”. Moussa (2011) characterized it as “a macro-level risk which can impair the stability of the entire financial system, as opposed to the risk of failure of an individual entity in the system”. Systemic risk is a condition that related to the possibility that a ‘trigger event’ - such as an aggregate negative shock in economic output, unemployment, or inflation, or a large fluctuation in interest rates, foreign exchange rates, or drop in market prices, or a large financial distress in a particular institution - results in negative effects to the whole financial system.

Systemic risk is understood, therefore, in relation to the concept of financial stability. Financial stability relates to the presence of confidence that key institutions of the financial system can continue to meet their financial obligations without interruption or outside assistance, and that the key financial markets allow participants to confidently transact in them at prices that relate to the fundamental forces rather than fluctuating substantially over short periods when there have been no changes in fundamentals (Crockett, 1997). It is part of the financial stability that, occasionally, some financial institutions may incur substantial losses and possibly default their obligations. It is part of the working of the market economy that financial institutions, like any other kind of business venture, may even go bankruptcy. However, in a financially stable system the losses, or default, or bankruptcy of a financial institution does not entail much harm to the rest of the economy, setting aside the direct negative effects on the customers (and, possibly, to the employees) of the financial institution itself. Indeed, the possibility to default provides a mechanism to

counteract the problem of moral hazard, where financial institutions may not be attentive enough in their investments if they are reassured that government intervention or any other kind of safeguard measure would prevent them from market failure anyway.

The potential effects of systemic risk - that is, what happens if the strategic risk materializes - can be devastating. In the worst scenarios, the consequences included the failure of financial institutions, with effects that result in credit shortage, liquidity freeze, and the paralysis of several markets that rely on inter-bank payment flows. At least, the materialization of the systemic risk may result in large losses of particular financial institutions and increased volatility in financial markets. Because of its potentially tragic effects on the entire financial system, systemic risk has been the object of several studies that especially focused on better understanding the possible sources and mechanisms that relate to the materialization of a systemic threat. Various sources and mechanisms of systemic risk have been discussed, including, for instance, the role of financial innovation (Merton, 1992; Kyrtsov and Sornette, 2013) and external shocks to the economy. Much research, however, has especially focused on at least three main areas of inquiry, namely the role of *liquidity*, the process of *contagion* between financial institutions, and the *structure of interconnections* between financial institutions.

Liquidity

In principle, defaults of financial institutions primarily take place because of insolvency. Insolvency happens when the “going concern” of a financial institution does not exceed the expected value of its liabilities (Brunnermeier et al., 2009; Haldane and May, 2011; Moussa, 2011). By itself, liquidity problems - that is, conditions where a financial institution temporarily lacks convenient and economy means of payment of obligations - do not necessarily entail that a financial institutions would default. However, also temporary lack of liquidity may occasionally escalate to more severe problems. This is especially the case in scenarios of financial crises, where the price of assets is weakly related to the ‘fundamentals’ (i.e., to the expected cash flow) and it rather reflect the value that market operators are immediately willing to pay for the assets (‘liquidity price’). Liquidity price may be significantly lower than the price based on fundamentals, for reasons that include the shortage of immediate buyers and buyers’ perception of the urgency to sell the asset. In financial crises, moreover, a financial institution with liquidity constraints may find it harder to access further funding sources.

Liquidity problems, therefore, may originate from both the financing and the market side. *Funding liquidity* is the phrase that refers to the ease or difficulty with which financial operators can obtain funding from other financial institutions or investors. Typically, financial institutions rely on various funding sources with different periods of ‘maturity’. When financial institutions heavily rely on relatively short-term funding sources (e.g., commercial papers or repo contracts), then they need to frequently renew (i.e., roll over) their debt. *Market liquidity*, instead, is the expression that refers to the ease or difficulty with which financial operators can raise money by selling the assets at reasonable price. When financial institutions raise cash by selling assets in conditions of urgency, then they need to accept relatively low prices. Depending on conditions of the financial system, therefore, liquidity problems may turn into more severe solvency issues if financial institutions face funding liquidity problems, or market liquidity problems, or both.

Contagion

If any ‘trigger event’ - such as an external shock to the economy or a liquidity problem or a credit default - hits a financial institution, the effects of this event may be circumscribed to the financial institution only. Under certain conditions, however, the trigger event may have repercussions also to other financial institutions through various kinds of mechanisms of contagion (or propagation). Some well-researched mechanisms include the ‘domino effect’ and the process of adjustment to price signals.

‘Domino effect’

The ‘domino effect’ refers to the concatenation of credit losses that one financial institution can stimulate to other economic operators, along a chain of credit-debt relationships. In a typical scenario, one bank borrowed from another bank. If the creditor bank incurs credit losses, then the bank can reduce its overall lending, including the lending to the debtor bank. If the debtor bank cannot find other funding sources, then it will reduce its own asset holding, including its lending to other banks (especially, if the bank cannot sell illiquid assets if not at immediate ‘fire sale’ prices). The debtor bank, therefore, may end up withdrawing funding from other banks, which - in turn - may react by reducing their own asset holdings and so on. The scenario, therefore, results in a ‘bank run’ where the financial institutions contract the overall amount of credit in the system, with potentially detrimental effects on the solvency of particular financial institutions and on the working of the economic system on the whole.

Brunnermeier et al. (2009) notice, however, that the ‘domino effect’ does not really pose a serious threat to financial stability. Setting aside the case where relatively large shocks take place, generally the effect of localized credit contractions does not escalate into the contagion of a large number of financial institutions. They argue, however, that the ‘domino effect’ may not fully capture the behavior that financial institutions may follow when facing credit contractions or other kinds of shock events. Indeed, other forms of contagion may take place between financial institutions, depending on how financial operators adjust their beliefs and expectations in face of the events and in anticipation of the possible defaults of other financial operators.

Adjustments to price signals

Another possible source of contagion between financial institutions originates from reactions triggered by apparently large price fluctuations. Financial institutions typically mark their balance sheets to market (i.e., accounting values are adjusted to reflect market values of assets). A reduction of market prices may result in losses that are inscribed into balance sheets of financial institutions, which may not have any credit-debt relationship with each other. A reaction from financial institutions, then, may be the one to sell some assets to restore its equity cushion, with the effect of depressing market prices even further and triggering losses on other financial institutions. Because of diffusion of such behavior, the single original price fluctuation may be amplified.

The spiral of losses triggered by a price fluctuation may also originate from a so-called ‘margin or haircut spiral’. A margin is a collateral that the holder of a financial instrument has to deposit to cover some or all of the credit risk of the counterpart. A haircut, instead, is a percentage that is subtracted from the market value of an asset that is used as collateral in a transaction. Margins and haircuts affect the maximum amount of leverage that a financial institution can adopt. Generally, margins and haircuts increase when asset prices decrease, and therefore they induce further contraction of credit. The increase of margins and haircuts stimulate a reduction of leverage and therefore sale of assets, that results in more price decrease and further increase of margins and haircuts, and so on (Brunnermeier and Pedersen, 2009).

The adjustment to price signals takes place especially because of three mechanisms (Brunnermeier et al., 2009). First, margins and haircuts are corrected in face of dropping

asset prices because risk measures are typically constructed on the basis of past performance data. The technique commonly employed - so-called Value-at-Risk (VaR) - are sensible to recent price falls in the past, that is incorporated into the model as a sharp increase in risk estimates. As in a typical ‘self-fulfilling prophecy’, the consequential fire sale of assets results in greater volatility of asset prices, hence providing an ex-post confirmation of the higher risk estimate. Second, margins and haircuts are corrected in face of dropping asset prices because the price drop is perceived as signaling increased volatility. Third, margins and haircuts are corrected in face of dropping prices because of an ‘adverse selection’ problem, in the sense that, as losses increase, financial institutions may be wary to receive assets as collateral because they may suspect that only low quality securities are used as collateral.

Structure of interconnections

The structure of interconnections between financial institutions also plays an important role in the propagation of the effects of ‘trigger events’ within the financial system. The structure of interconnections refers to the network of credit-debt and risk relationships between financial institutions. Research done in this areas (Battiston et al., 2009; Gai and Kapadia, 2010; Halaj and Kok, 2013; Moussa, 2011; Nier et al., 2007) has shown that the structure of interconnections - e.g., the degrees to which the financial network is more or less concentrated or fragmented - plays an important role in whether ‘trigger events’ result in widespread damages to financial stability or not. This kind of studies have important implications for better understanding sources of financial instability that may be not so apparent from the analysis of financial institutions alone, or from the dyadic relationship between any couple of two financial institutions and of their credit-debt and risk relationships. Indeed, analysis of the structure of interconnections results in original insights that have repercussion on financial stability policies, including the so-called ‘macro-prudential’ regulation that will be discussed later.

An instance of research on the role of the structure of interconnections between financial institutions is provided by the study of Gai et al. (2011). Their network model of the banking system is intended to study what happens when shocks affect the availability of interbank loans, i.e., the consequences of a ‘funding liquidity shock’. Any single bank reacts to the effects of the shock by reducing its interbank loans. The overall effect of the shock on the financial network, however, resulted strongly dependent on properties of the

network structure (needless to say, nowadays' financial systems are relatively complex, where securitization resulted in the lengthening of the intermediation chains). Greater complexity and concentration of the financial network, in particular, resulted in greater fragility of the financial system.

Several other works resulted in explanations for the role of heterogeneity across financial institutions, distributions of exposures, and tiered network structures (Moussa, 2011). Generally, results of these studies are controversial and partially counterintuitive. Nier et al. (2007) found that, in well-capitalized networks, greater connectivity tends to increase contagion up to a certain threshold, above which further connectivity entails a reduction of contagion. In under-capitalized networks, instead, greater connectivity makes the financial system more prone to contagion in any case. Battiston et al. (2009), instead, highlighted that an increase in connectivity improves resistance to contagion if the initial connectivity is low, while further connectivity increases the risk of contagion if connectivity is already high. Haldane and May (2011), moreover, highlight that excessive homogeneity within a financial system—when all banks tend to follow the same investment criteria and tend to have similar exposures—can minimize risk for each individual bank, but maximize the probability of the entire system collapsing.

Findings from these research suggest that detailed attention to the structure of interconnections is needed to understand how originally circumscribed events may 'snowball' into larger systemic effects. A key insight, here, is that features of the network ties may act either as 'shock transmitters' or as 'shock absorbers' (Nier et al. 2007), depending - among other factors - on the level of connectivity of the whole network. If connectivity is low, more network ties amplify the possible channels for contagion. If connectivity is high, more network ties help spreading losses among a larger number of counterparts, so that the loss for each of them is relatively small. But also capitalization counts: in under-capitalized networks, even a small loss can lead to a default of the counterpart (Battiston et al., 2009). There may be also a role for the overall size of the network, where larger financial systems seem to be relatively more resilient to contagion.

Within the area of study of systemic risk, special attention has been placed, in particular, to the role of derivatives (Hentschel and Smith, 1996). By their very nature, derivatives make counterparts exposed to the risk that a single shock to the economy may have large

repercussions across many actors. Trigger events such as a sharp fluctuation of prices, or interest rates, or foreign currency exchanges, or - more relevantly - a credit default, may result in the materialization of large obligations in several financial institutions; credit protection sellers may find themselves called to cover losses incurred because of the default of the underlying asset debtor; credit protection buyers may rush to hoard the defaulted securities and may not be able to find them in a liquid market, and, in the worst scenario, they may not be able to receive the credit protection that they expected.

The threat posed by derivatives on the position of a financial institution, moreover, is heightened if its dealers do not carefully take safeguarding measures, such as careful monitoring of counterparty risk, diversifying risks across uncorrelated markets, maintaining adequate capital cushions, and possibly establishing highly rated special-purpose subsidiaries to conduct derivative business (Kyrtsov and Sornette, 2013).

As a matter of fact, however, sometimes financial institutions that exchange derivative contracts hold unsecured exposures that exceed capital, even to a single counterpart. The risk held by these financial institutions may be relevant for financial stability, especially if the institution is a 'Systemically Important Financial Intermediary' (SIFI), that is, a financial operator whose default has significant repercussions on the whole financial system. A study conducted in 2009 by the rating agency Fitch (Marcose, 2012) identified that 12 SIFIs accounted for about 78% of all bilateral derivative exposures (up from 67% that had been reported the previous year). Even more significantly, the top five financial institutions accounted for 95% of total notional amount that was bought and sold. In such scenario, the financial system may be overtly dependent on the robustness of a few SIFIs - that, arguably, may result, because of the topology of network ties, in 'too interconnected to fail' (TITF) financial institutions, where any failure of a SIFI may bring down other financial operators in a cascading fashion.

3.2 Macro-Prudential Regulation

Because of potentially devastating effects on financial stability, systemic risk has been subjected to high scrutiny from the side of academics, policy-makers, central banks, and financial regulatory authorities. The main issue in counteracting systemic risk originates from the fact that, as highlighted by Faubus (2010), systemic risk bears the traits of the 'tragedy of the commons'. In the original formulation, the tragedy of the commons (Hardin, 1968) refers to the lack of cooperative behavior that results in the over-exploitation of

natural resources. In the present context of discussion, the tragedy of the commons arises because financial institutions lack the incentives to cooperate in preventing threats to financial stability, provided that individuals reap the benefits of exploiting finite capital resources while they do not fully internalize the costs of their over-exploitation. On this basis, concerns with systemic risk generally result in advocacy for public policies intended to safeguard the stability of the financial systems.

That financial stability should be a public policy objective is generally uncontested nowadays. Reasons for public authorities' intervention to preserve financial stability especially include the argument that the financial system is dangerously exposed to instability threats, and that sources of instability can propagate to the rest of the financial system with potentially widespread negative effects (externalities) (Crockett, 1997). Instability threats originate from various conditions attached to contemporary finance, including the growth in the volume and volatility of financial transactions, the increased integration of capital markets, the rise of international capital flows, the cognitive challenges to understand the complex risk structures that originate from securitization and diversification of investments, and the adequacy of risk management models and tools to keep risk under control. The possibility that localized instability escalates to widespread effects, moreover, is related to delicate conditions about financial institutions' vulnerability to 'runs', contagion mechanisms, and perceptions of financial institutions' liquidity and solvency.

The main policy approach to cope with systemic risk is commonly known as '*prudential*' or '*macro-prudential*' regulation. The term, that originated within the Bank for International Settlements (BIS) in the 1970s (Clement, 2010), refers to the containment of collective-level risk taking into consideration both individual (financial institution-specific) risk and joint (or correlated) risk that financial institutions have with other ones (Acharya, 2009). The general goal of macro-prudential policy is to limit the risks and costs of systemic crises (Galati and Moessner, 2013). For Brunnermeier et al. (2009), macro-prudential policy is primarily intended to stabilize the financial system with respect to the tendency of reducing measured risk in booms and increasing measured risk in busts. Perotti and Suarez (2009) conceived macro-prudential policy as primarily aimed to discourage individual behavior that may cause systemic risk or spread negative externalities across the financial system.

For Hanson et al. (2011), macro-prudential policy should aim at controlling the social costs of a generalized reduction of assets in the financial system.

Macro-prudential policy is generally designed with the intention to contain two potential sources of financial instability and diffusion of instabilities to the whole financial system. First, macro-prudential policy is concerned with containing fluctuations of risk over time, especially in relation to the tendency of the financial cycle to amplify the boom and bust of the business cycle (i.e., the ‘pro-cyclicality’ of the financial system). A typical policy approach, in this respect, is to require financial institutions to build up a capital cushion in good times, which could help covering losses in bad times. Second, macro-prudential policy is also concerned with containing risk that is especially concentrated in particular areas of the financial system that are also extremely interconnected with other financial institutions (i.e., SIFIs). A policy response here, which has gained an increased attention during the last years, is the one to tailor regulatory requirements to the systemic significance of individual financial institutions, i.e., their contribution to overall risk. In this way, particular financial institutions would be subjected to different requirements depending on how disruptive their default would be for the financial system.

The adoption of macro-prudential regulation as a way to counteract systemic risk also builds on the belief that market forces, by themselves, are not able to ensure the stability of the financial system. In principle, if financial operators are ‘left on their own’ then they might exercise more care in their financial decisions with respect to the scenario where the intervention of public authorities makes them more inclined to take risks. In practice, however, sources of instability in the financial system may originate from events that are infrequent, or that cannot be predicted, and over which financial institutions have no control. Even if public authorities commit not to intervene on the financial system, moreover, they may find it politically or economically advantageous to step in and restore financial stability once the disruption to the financial system has already happened. In anticipation of this, therefore, the decisions of the financial institutions are not immune by moral hazard anyway.

A traditional way for public authorities to maintain financial stability has typically been the use of ‘safety nets’, especially in the form of deposit insurance schemes and of the presence of a lender of last resort. Deposit insurance schemes have been widely adopted as tools of

financial stability in the world, albeit - by themselves - they induce insured depositors to relax their efforts to monitor the borrowing institutions. Borrowing institutions, in turn, may be induced to pursue risky strategies because of the expectation that public funds would in any case rescue the loss of capital. The lender of last resort, instead, provides that financial institutions would receive liquidity support if needed, in order to avoid a 'fire sale' of assets that would generate losses and possibly lead to insolvency. The lender of last resort results in moral hazard problems, if financial institutions are safe that the lender of last resort would always provide the necessary liquidity. In part, this issue is tackled by the 'constructive ambiguity' (Corrigan, 1990) of central banks that may, in principle, intervene to provide the necessary liquidity but they do not provide assurance of this to any particular institution. Practically, however, it seems that public authorities can hardly restrain themselves from assisting financial institutions whose default has large negative repercussions on the rest of the financial system, especially because of their relative large size (i.e., 'too big to fail').

Setting safety nets aside, public authorities rely on other forms of intervention to support financial stability, namely regulation to protect franchise value, regulation to support market forces, and capital requirements (Crockett, 1997).

Regulation to protect franchise value

One way to maintain stability of the financial system is to contain the sources of industrial change and innovation. Until about the 1970s, many countries used to adopt public policies that effectively limited entry to the financial industry, provided restrictions on interest rate competition, and tolerated collusion practices. Commercial and investment bank activities were kept segregated from each other. When a default happened, the consequences on the financial system were relatively modest and typically public authorities could intervene to salvage the defaulted company. During the last decades, however, liberalization and deregulation policies increased competition in the financial sector, with the effect to make the financial system more vulnerable to sources of instability.

Regulation to support market forces

Another way to maintain stability of the financial system is to induce financial operators to self-regulate their behavior. In principle, the 'tragedy of the commons' of financial stability arises exactly from the apathy of financial institutions towards externality effects of their

potential default. However, financial institutions share the concern of public authorities to monitor their exposure to risk in order to better manage their portfolios. Public authorities may induce, therefore, financial institutions to make use of their internal risk assessment models (subjected to external validation) for determining the extent to which they should be subjected to regulatory intervention (e.g., amount of capital requirement). This approach to macro-prudential policy has gained attention at the Basel Committee on Banking Supervisions and it has been incorporated into their Capital Accord.

Regulation to set risk-based capital requirements

Lastly, another way to maintain stability of the financial system is to set risk-based capital requirements, that is, demanding financial institutions - especially banks - to hold a minimum amount of capital in relation to their risk-weighted assets. Originally introduced with the Basel I regulation in 1988 (and followed by 2004 Basel II and by the Basel III that is currently being implemented), capital requirements constitute the cornerstone of contemporary financial regulation (Brunnermeier et al., 2009). Basel capital requirement regulation have been progressively refined over time, with an increased sensitivity to different classes of assets in relation to their risk and to different ‘tiers’ of capital. In general, capital requirements are expected to reduce the likelihood that a financial institution defaults, and larger financial institutions that hold relatively riskier weighted asset portfolios are required to hold higher amounts of capital than smaller and relatively less risky ones.

Although capital requirements have resulted in making the financial system apparently more stable, nevertheless they may not completely shield the financial system from the negative externalities associated with systemic risk. One limitation of the capital requirement policy to counteract systemic risk is that capital requirement rules apply to ‘regulatory capital’ (i.e., the minimum capital required by the regulator), while financial decisions made by financial institutions are affected by their ‘economic capital’ (i.e., the capital required to cover losses within a certain confidence level) (Elizalde and Repullo, 2007). Accordingly, some financial decisions result in increased risk to the portfolios of financial institutions (e.g., through the use of credit derivatives) but these decisions do not have any effect on capital requirements because they do not impact regulatory capital. Another limitation of capital requirement policy is that evidence from past financial crises showed that financial institutions with relatively small risk exposure (e.g., in terms of size

of their balance sheet) can nevertheless pose significant risk of contagion to the whole system.

Concerns with the limitations of capital requirements and other policies for dealing with systemic risk are heightened by the increased role of derivatives in the contemporary financial system. The use of OTC derivatives, in particular, entails that financial institutions are exposed to risks that, on the one hand, have profound repercussions on financial stability while, on the other one, are not taken into consideration in the ‘standard’ macro-prudential tools. As a matter of fact, derivative contracts made outside the exchanges have been largely unregulated in the past, especially at the time of the outbreak of the 2007-08 financial crisis: for example, in the US CDS were exempt from regulation by the Commodity Futures Trading Commission (CFTC) under the Commodity Futures Modernization Act (CFMA) of 2000, the Securities and Exchange Commission (SEC) has limited authority to enforce federal securities laws, and the Federal Reserve (Fed) lacked information about derivatives transactions that were not subjected to central clearing or recorded in trade repositories (Kiff et al., 2009). In all effect, at the time when the 2007-08 financial crisis erupted, the financial system lacked information about the exposure to systemic risk originating from derivatives, as well as prudential tools for shielding the financial system from negative externalities that could originate from derivatives defaults.

The 2007-08 financial crisis (also termed, nowadays, as ‘Great Financial Crisis’ or GFC) marked a fundamental rupture in the policy approach towards systemic risk. The kind of potential cascades of defaults of financial institutions that could take place in those years paralleled only those that had been experienced in the Great Depression, but under conditions of greater complexity of the financial system. The dramatic experience of the Great Financial Crisis stimulated widespread awareness of the need for a *macro-prudential or systemic risk regulator*, which would especially focus on protecting financial stability vis-à-vis sources of instability and negative externalities effects across the network of relationships between financial institutions (Bliner, 2010). In order to better understand the context where contemporary ideas about *systemic risk regulation* originated - and, in particular, about *macro-prudential regulation of financial derivatives* - next sections will briefly recall the trajectory of the Great Financial Crisis and the role that derivatives played in pushing the financial system on the edge of meltdown.

3.3 On the Edge of the Meltdown: The Great Financial Crisis

Reviewing the events that led to the 2007-08 Great Financial Crisis is important in order to gain a better understanding of the conditions of the contemporary financial system and the role of derivatives as source of systemic risk. During the twenty years before 2007, the financial system enjoyed a prolonged period of relative stability and contained fluctuations, a phenomenon that - also in conjunction with relative growth of GDP in most countries and low inflation - was optimistically called ‘the great moderation’ (Kyrtsov and Sornette, 2013). Before the Great Financial Crises came, most of pivotal actors of the international financial and monetary system (from the academia, the public authorities, and the financial professions) confidently praised the success to attain financial stability: as Frederic Mishkin (2007) argued, “Fortunately, the overall financial system appears to be in good health, and the U.S. banking system is well positioned to withstand stressful market conditions”. The ‘good health’ suddenly vanished in a few months’ time.

There is no shortage of scholarly and professional works that aimed to reconstruct, analyze, interpret, and explain the events that triggered the Great Financial Crisis and its unfolding (a review of several book is provided by Lo, 2012). No single causal factor has been clearly identified for the origination of the Great Financial Crisis, which can be related to a combination of conditions that include global capital flows, poor regulation, regulatory capture, inequality, high leverage, skewed economic incentives of borrowers and lenders, etc. (Dam, 2010; Kallestrup, 2012; Stout, 2011). The Reports of the US Financial Crisis Inquiry Commission (Angelides and Thomas, 2011) and of the EU Liikanen Commission (Liikanen, 2012) offer some detailed and enlightening insights into the ‘trigger events’ of the Great Financial Crisis, how sources of financial instability extended across the network of financial institutions, and how the meltdown of the financial system was prevented - albeit, at the cost of massive spending of taxpayers’ money to restore liquidity, solvency and credibility of financial institutions.

The Great Financial Crisis unfolded along a process that can be divided into different stages (Helleiner, 2011; Roubini and Mihm 2010). The Liikanen Report identified five ‘waves’.

Wave one: “The subprime crisis phase” (mid-2007 to September 2008)

During the decade before the outbreak of the Great Financial Crisis, various conditions related to global capital inflow, low interest rates, and deregulation of financial services

resulted in escalating prices of houses in the US (Crotty, 2008). The frenzy in the US house market especially originated from advantageous borrowing conditions for American households, especially in the form of sub-prime mortgages (i.e., mortgages accorded to individuals who historically have difficulty to maintain repayment schedule). Brokers of mortgage companies progressively intensified the relaxation of credit check conditions to the issue of loans (Jickling, 2009), that were eventually provided even to so-called ‘NINJA’ borrowers (i.e., No Income, No Job or Assets). The generous concession of loans resulted in a remarkable over-leverage of the US financial system: by the mid-2000s, the ration of household debt to GDP had raised above 100% (the last time the level of debt was more than 100% of GDP was in 1929, at the beginning of the Great Depression; Reavis, 2009).

The growth of sub-prime mortgages was part of a more general financial scheme that has been described as the ‘originate to distribute’ (OTD) strategy (Wilmarth, 2009). The OTD strategy included the provision (origination) of consumer and corporate loans (including the sub-prime mortgages), the packaging of loans into asset-backed securities (ABS) and collateralized debt obligations (CDO), the creation of OTC derivatives based on the underlying ABS and CDO securities, and the distribution of these securities to investors. The OTD strategy enables financial institutions to increase income from commission fees, to transfer to investors the risks associated with the securitized loans, and to expand the amount of credit given. During the 2000s, the OTD strategy resulted especially profitable and viable, also in relation to the growing demand for high yield products from the side of investors (Crotty, 2008). As an indicator of the growth of the OTD strategy, the amount of global CDO issuance increase from \$ 150 billion in 2004 to \$ 2 trillion in 2007 according to the Securities Industry and Financial Markets Association (Sornette and Wooddard, 2009).

Already in 2005, some sub-prime mortgage holders started defaulting their payments. The losses that two sub-prime hedge funds incurred resulted in the temporary closure of the market for asset-backed commercial papers and in July a German financial institution (Deutsche Industriebank IKB) was not able to roll over its short term funding. Losses from the repayment of subprime mortgages intensified in 2007, when financial institutions started liquidating their residential mortgage-backed securities. The sale of these assets resulted in a sharp decrease in prices of sub-prime securities (up to –80% by December 2007), but also in other (more quality) tranches. The widespread sale entailed that the

market for mortgage-backed securities became illiquid, and that holders of these troubled assets could hardly find any seller of credit protection.

The lack of liquidity in the mortgage-backed securities market - and, relatedly, in other parts of the inter-bank markets more generally - triggered liquidity problems in some financial institutions. In September 2007, Northern Rock applied for emergency liquidity aid from the Bank of England (eventually, the financial institution was nationalized in February 2008). Public authorities reacted to the signs of financial distress by supplying liquidity to the inter-bank market (the ECB, for instance, intervened in August 2007 with €95 billion and in December 2007 with € 300 billion).

Wave two: "The systemic crisis phase" (as of September 2008)

In September 2008, Lehman Brothers collapsed and the financial crisis suddenly escalated to the systemic level. Liquidity issues became apparent in other main financial institutions, especially American International Group (AIG). Perceptions that financial institutions were not financially solid, and that the government would not necessarily step in to salvage them, triggered panicked sales of assets. Prices of several financial assets (including bank stocks) fell sharply, volatility in global capital markets peaked, and credit spreads intensified. Liquidity in the financial markets dried up, with the effect to make it more difficult and expensive for financial institutions to short term refund (Schwarcz, 2009). The development of global finance in the previous years, in addition, had resulted in complex international relationships between financial institutions, with the effect that defaults of financial institutions in a country could potentially threaten financial stability in other countries.

Extreme measures were taken by governments in the world to sustain liquidity in the financial system. Public authorities eventually decided to rescue largest financial institutions, on the basis of the argument that their bankruptcy would be detrimental for financial stability because of their size (i.e., the 'too big to fail' doctrine) and their ties with the rest of the financial network (i.e., the 'too interconnected to fail'). In the US, for instance, a massive governmental intervention was required to salvage AIG, Merrill Lynch, Fannie Mae, Freddie Mac, Washington Mutual, and Wachovia (Helleiner, 2011), although these actions did not prevent hundreds of smaller banks in the US to fail in the period 2008-2010 (Blinder, 2010). The threat of the financial meltdown, moreover, extended far beyond

the US. The governments of the UK and the Netherlands, for example, had to provide guarantees to protect the funds that their depositors had put in Icelandic banks, that were rapidly hit by the financial storm.

Wave three: "The economic crisis phase" (as of 2009)

While the negative externalities of the financial crisis were contained by government interventions, public authorities turned their attention towards restoring financial stability and reinvigorating the distressed real economy. The Financial Stability Board (FSB), established in April 2009, started working closely with the Basel Committee on Banking and Supervision on the creation of new rules for capital, liquidity and trading requirements, that eventually resulted in the formulation of Basel III principles in September 2010. A period of relative stability of market prices helped financial institutions to recover their financial solidity and improve profitability. However, it became apparent in 2009 that the real economy had been severely hit by the financial crisis and that exceptional measures were needed to help the recovery of business enterprises and consumption spending. These measures, however, came at the cost of increased sovereign debt.

Wave four: "Sovereign crisis phase" (as of 2010)

The last stage of the Great Financial Crisis is the exacerbation of public finances, especially in industrialized countries. The level of public debt in relation to GDP grew most notably in peripheral EU countries, such as Portugal, Spain, Italy, Ireland, and Greece. The Greek public finance conditions were especially troubled, and widespread concerns with the possible default of Greek debt triggered the special intervention from the EU and the IMF, that provided a € 110 billion rescue package to the country in May 2010 (also, a € 750 billion emergency fund was created to support other weak EU economies). After some indication that Greece could not be able to meet budgetary targets anyway (and the downgrade of Greece's sovereign debt to CCC in June 2011), an additional support package of € 190 billion was provided in July 2011. Later on, it became apparent that Greece could not meet even the terms of the second rescue package, and, after lengthy negotiations, eventually private holders of Greek debt accepted a 78% net present value haircut on their positions in March 2012.

Growing concern with the difficulty that EU banks experienced in accessing the capital market induced the European Central Bank (ECB) to offer a special scheme called "Long-

Term Refinancing Operations” (LTRO) that provided banks with the possibility to take up loans to be repaid within three years at a 1% interest rate. In total, 523 banks participated for an aggregate amount of € 489 billion in December 2011 and about 800 banks took part for an overall amount of € 529 billion in February 2012. The LTRO operations assisted restoring financial solidity into the EU system, although they also elicited concerns that the EU banks could have used the liquidity to invest in government bonds - therefore possibly increasing their exposure to the troubled central banks of EU peripheral countries. It was uncertain, moreover, whether the LTRO operations eventually resulted in more credit access to small-medium enterprises, households, and other borrowers.

Wave five: “The crisis of confidence in Europe”

The possibility that EU governments might default their sovereign debt put pressure on European banks, that investors suspected to hold large shares of government bonds. Access to capital markets deteriorated for European banks, whose stock prices started exhibiting signs of greater volatility. Concerned with the stability of the European financial system, the Committee of European Banking Supervisors (CEBS) and, later, the European Banking Authority (EBA; established on 1st January 2011), in cooperation with the European Systemic Risk Board (ESRB) started conducting ‘stress test’ exercises to assess the resilience of financial institutions to adverse market developments (stress tests were conducted in 2009, 2010, 2011 and 2014). The stress tests highlighted the levels of exposure of the European banking system to sources of risks to financial stability and informed subsequent measures, especially in terms of targeted requirements on individual institutions.

Explaining the origin and unfolding of the Great Financial Crisis is beyond the aims of the present work. For the sake of better understanding how the outbreak of the Great Financial Crisis relates to the materialization of systemic risk that threatened the financial stability of the US, the EU, and of other financial centers in the world, however, it may be relevant to highlight the importance of features of the institutional and regulatory environment where the Great Financial Crisis took place. While various factors may have played a role in triggering the crisis in 2007, in fact, attention should be also placed on the ‘rules of the games’ of the financial system that operated at that time, if we are to argue for why the crisis took place at that particular time in history. In this respect, indeed, some scholars argue that changes of financial regulations that took place in the between the 1980s and the

2000s contributed generating an environment that was favorable at least, if not conducive to, the ‘trigger events’ of the Great Financial Crisis (Stout, 2011; Samuel, 2009; Wilmarth, 2009).

For most of the twentieth century, the financial system was regulated through a relatively prudent arrangement, which originated from reactions to the speculative excesses of the late 1920s (which, in turn, are generally related to the failure of thousands of banks in 1930s and to the origins of the Great Depression). Concerned with preventing individual financial institutions to take on too much risk, in 1933 US policy-makers enacted the Glass-Steagall regulatory system, which included the separation of commercial banking, investment banking and insurance activities, that was intended to prevent the use of bank deposits for speculative purposes.

In the 1970s and 1980s, various economic and political conditions coalesced to undermine the Glass-Steagall regulatory system (Samuel, 2009). On the one hand, rising inflation, increased global trade, and the Savings and Loan crisis induced reconsideration of the adequacy of the regulatory system to help financial institutions cope with a changed financial environment and preserve them from misbehaving. On the other one, liberalism ideology - in the form embraced by Thatcher and Reagan - resulted in favorable circumstances for re-regulating the operation of financial services. London Stock Exchange’s ‘Big Bang’ on 27th October 1986 (when several new regulations of the city’s exchange came into force) provided a relevant instance of the changed policy orientation towards the de-regulation of financial services and the opening of venues for innovative products in the financial market. In the same year, the Federal Reserve in the US reinterpreted the Glass-Steagall regulatory system in the sense that a bank could derive up to five per cent of revenues from investment banking activities.

The progression towards greater de-regulation of financial services intensified. In the US, in 1996 the Federal Reserve further adjusted the reinterpretation of Glass-Steagall allowing banks to earn up to 25% revenues from investment banking activities. In 1998, US regulators allowed Citicorp to merge with Travelers, resulting in the world’s largest financial services company that included commercial banking, investment banking and insurance business areas. In 1999, the Gramm-Leach-Bliley Act (also known as the Financial Services Modernization Act) repealed part of Glass-Steagall Act that provided

separation between banking activities. In 2000, the Commodity Futures Modernization Act prevented the Commodity Futures Trading Commission from regulating most OTC derivatives (including CDS). By the years 2000s, then, the institutional and regulatory conditions in the main world financial markets had come to largely tolerate innovative forms of financial services and products.

The changed regulatory system provided a fertile ground for enhanced financial activity. The US credit market debt was 168% of GDP in 1981 and it totaled 350% in 2007; financial assets were about five times larger than GDP in 1980 but they become ten times larger in 2007; the notional value of all derivative contracts amounted to about three times global GDP in 1999 but they became more than eleven times in 2007; the notional value of CDS derivatives was about \$ 6 trillion in 2004 but they become \$ 62 trillion in 2007 (Crotty, 2009). These development were largely led by the main financial services firms - especially, companies like Merrill Lynch, Morgan Stanley, Goldman Sachs and Lehman Brothers that, by 2006, had gained the status of 'universal banks' (Wilmarth, 2009).

3.4 The Role of Derivatives in the Great Financial Crisis

Several scholars and analysts agree that, while derivatives did not trigger the Great Financial Crisis, nevertheless they largely contributed to creating the conditions for the fragility of the financial system and to escalating early defaults to larger threats to financial stability. Among derivatives, a primary role in the financial crisis was played by Credit Default Swaps (CDS), which were largely concentrated in a relatively small number of financial institutions. While CDS primarily serve the objective to transfer risk of default in an underlying credit asset, during the 2000s massive amounts of CDS were traded for speculative purposes. Financial institutions build up large amounts of CDS in their portfolios, which - because of the limits of accounting standards and disclosure requirements - were not generally properly tracked and communicated to the public. The lack of information on the CDS held by financial institutions, together with their increased leverage, resulted in the increase of systemic risk: once the value of US houses plummeted, mortgage holders started defaulting their payments, and liquidity dried up, CDS could potentially bring down a number of financial institutions, had public authorities not stepped in to salvage the financial system of most industrialized countries.

At least four features of credit derivatives made them play such a significant role in the Great Financial Crisis, namely the lack of information about CDS exposure, the complexity of CDS products, hidden leverage, and concentration of risk.

Lack of information: First, credit derivatives (like all OTC derivatives more generally) were not typically disclosed with adequate detail. Despite several calls in the past for more transparency from public and supervisory authorities, such as BIS and IMF, generally financial institutions did not provide detailed information about credit derivatives that they held in their portfolios. Setting aside some disclosure of notional amounts and market values, financial institutions did not provide information about counterparts and risks involved with their CDS contracts (Acharya et al., 2009). As an effect, other financial operators could not assess how risky the position of financial institutions was because of the CDS contracts already in place. In addition, no public or supervisory authority could access centralized information about CDS contracts present in the financial system, with the result that no assessment could be made of the overall risk that derivatives posed to financial stability (especially, an assessment of whether different CDS contracts were correlated with each other).

Complexity of financial products: Second, credit derivatives consisted of highly complex financial products, whose complete understanding largely surpassed the cognitive abilities of the typical trader. Differently from exchanged derivatives, which are standardized, OTC derivatives are custom contract that are bilaterally negotiated between parties. As such, OTC contracts are typically illiquid and difficult to price. The value of these contracts, therefore, could be only assessed on the basis of complex mathematical models. Further complications arose, however, because of the subjectivity involved in determining when a ‘credit event’ occurs and because of the difficulty to assess the creditworthiness of counterparts if they had extensive and complicated exposures to derivatives in their portfolios. As a matter of fact, the assessment of the value of credit derivatives depended on systems that appeared ‘cryptic’ to the same financial institutions’ users - the result of mathematical models implemented through specialized algorithmic coding in computerized systems.

Leverage: Third, credit derivatives enabled financial institutions to significantly increase their leverage (i.e., debt/equity ratio) in a hidden way. Credit derivatives like CDS started to

be used in conjunction with other credit derivatives, especially Collateralized Debt Obligations (CDOs) (D'Souza et al., 2009). CDOs consisted of asset-backed securities that derived their value from portfolios of underlying assets, such as mortgages, corporate bonds, and credit card debts. These debts were converted into different 'packages' and sold as securities, with the underlying assets serving as collateral. These securities were often sold in 'tranches', where the first (equity) tranche bore most of the risk (and return) and other tranches held less risk (and return). The CDOs were typically held by banks as off-balance-sheet assets. Because of the lack of information about credit derivatives, the leverage of financial institutions was hidden to the eyes of other financial operators. Credit derivatives, therefore, were used as a 'secret lien' (Simkovic, 2009) that made financial institutions appear more creditworthy than they actually were. By hiding the amount of risk exposure, financial institutions were able to increase their leverage at disproportionate levels: Goldman Sachs, for example, possessed about \$40 billion of equity in front of \$1.1 trillion of assets, and Merrill Lynch had about \$30 billion of equity for \$1 trillion of assets (Crotty, 2009).

Concentration of risk: Fourth, credit derivatives resulted in massive concentration of risk in financial institutions that served as 'hubs' of several counterparts. Credit derivatives enables financial operators to transfer risks to other market actors that were willing, upon receipt of a fee, to take on the risk. Over time, some financial institutions accumulated immense risk positions, that eventually exposed them to large losses when the counterparts claimed to receive the credit risk protection. The concentration of risk, moreover, was typically related to the adoption of the 'originate to distribute' model, that induced financial institutions to create credit risks first through the concession of sub-prime loans, then to securitize them, and then to sell packaged credit securities through the capital market. Credit derivatives served the purpose to shift risk away from the financial institutions that created credit risks through the concessions of sub-prime loans on the one hand, and to gain commission fees for taking on concentrated risks (typically, through subsidiaries of main bank groups) from other financial operators.

The combined effect of these features of credit derivatives resulted in an increase of systemic risk. When US mortgage holders started to default and the crisis hit the market, the price of collateralized credit securities, such as CDOs, plummeted. Rating agencies responded by downgrading these products, that lost additional market value therefore. The

presence of credit derivatives (especially CDS) resulted in losses for the financial institutions that were expected to provide credit protection. Losses triggered margin calls, that financial operators could only provide by fire-selling safer assets (the only ones that had market). The market price of assets and derivatives went down, because of both the massive sale and the lack of reliable information about their value. The capital of banks evaporated as they valued securities according to their estimated current value. As a consequence, banks reduced credit, both to non-bank operators and then also to other banks in the inter-bank market.

How could credit derivatives come to exercise such an influential role? In part, the answer can be found in the features of the regulatory environment - namely, in the progressive formulation of legislation that favored the explosion of credit derivatives while lacking the means for keeping the use of such derivatives under control. In the modern era, derivatives were originally regarded for their function to protect business from accidental events (e.g., a farmer that protected his business from the risk of price fluctuation of crops). The speculative use of derivatives, instead, was highly criticized - and legally restrained - because of its lack of social benefits. During the last decades, however, various legislative interventions in the US progressively removed barriers to the use of derivatives, or even introduced advantageous consequences from the use of derivatives. In the opinion of some scholars (Crotty, 2009; Simkovic, 2009; Stout, 2011), we should exactly look at the changes of legislation and regulation of derivatives over the last decades in order to identify the conditions that made derivatives play an influential role in the mounting of the crisis.

The way changed legislation opened up possibilities for the speculative use of derivatives is highlighted by Stout (2011), who argued that the Commodities Futures Modernization Act (CFMA) of 2000 dramatically changed the way finance operated. The author highlighted that, since the nineteenth century, the common law had developed the so-called 'rule against difference contracts' doctrine, that considered derivative contracts (also called 'difference contracts' in the past) as unenforceable gambles if they did not serve hedging purposes. For example, in a case (*Irwin v. Williar*) discussed in 1884, the US Supreme Court explained:

“The generally accepted doctrine in this country is . . . that a contract for the sale of goods to be delivered in the future is valid, even though the

seller has not the goods, nor any means of getting them than to go into the market and buy them; but such a contract is only valid when the parties really intend and agree that the goods are to be delivered by the seller and the price to be paid by the buyer; and, if under guise of such a contract, the real intent be merely to speculate in the rise or fall of prices, and the goods are not to be delivered, but one party is to pay to the other the difference between the contract price and the market price of the goods at the date fixed for executing the contract, then the whole transaction constitutes nothing more than a wager, and it is null and void.”

The lack of juridical protection of speculative derivatives resulted in the creation of privately organized exchanges, where clearinghouses provided the private enforcement of these contracts. In 1936, the Commodity Exchange Act (CEA) confirmed that speculative derivatives trading was confined to the organized exchanges. These institutional arrangements, however, were progressively dismantled since the 1980s. In 2000, the CFMA effectively legalized, for the first time in US history, the speculative trading of OTC derivatives. After the CFMA, the aggregate volume and value of derivatives (especially, OTC credit derivatives) skyrocketed, and the stage for the financial crisis had been prepared.

Another feature of the US legislation that contributed to make derivatives play an important role in the Great Financial Crisis was the exceptional status of derivatives in bankruptcy procedures (Crotty, 2009). Since the 1970s, the US Bankruptcy Code gives creditors in derivatives transactions special rights and immunities in the bankruptcy process, including unlimited enforcement rights against the debtors (the so-called ‘safe harbor’ attribute). These special provisions for derivatives grew over time under the lobbying pressure of the financial industry on the US Congress, on the basis of arguments that the financial system (especially, the commodities futures market) would be otherwise too fragile. The special protection of derivatives, however, later expanded to include any kind of derivative contracts, especially including swaps. Given that the safe harbor for derivatives enables the derivative creditor to terminate the contract and to take possession of the collateral of the derivative debtor in case of bankruptcy, the special protection of derivatives results in the downplaying of the counterpart risk. As a consequence, the preferential treatment of derivatives accorded by the Bankruptcy code also helps explaining the growth of

derivatives before the crisis, as well as the amount of risk exposure that financial institutions were willing to take on.

Both features of derivatives and special conditions included in the US legislation, therefore, help explaining the role that derivatives contracts played in the Great Financial Crisis. According to the Report of the US Financial Crisis Inquiry Commission (2011), derivatives contributed to the Great Financial Crisis in three ways:

“First, one type of derivative—credit default swaps (CDS)—fueled the mortgage securitization pipeline. CDS were sold to investors to protect against the default or decline in value of mortgage-related securities backed by risky loans. Companies sold protection—to the tune of \$79 billion, in AIG’s case—to investors in these newfangled mortgage securities, helping to launch and expand the market and, in turn, to further fuel the housing bubble.

Second, CDS were essential to the creation of synthetic CDOs. These synthetic CDOs were merely bets on the performance of real mortgage-related securities. They amplified the losses from the collapse of the housing bubble by allowing multiple bets on the same securities and helped spread them throughout the financial system. Goldman Sachs alone packaged and sold \$73 billion in synthetic CDOs from July 1, 2004, to May 31, 2007. Synthetic CDOs created by Goldman referenced more than 3,400 mortgage securities, and 610 of them were referenced at least twice. This is apart from how many times these securities may have been referenced in synthetic CDOs created by other firms.

Finally, when the housing bubble popped and crisis followed, derivatives were in the center of the storm. The insurance company American International Group (AIG), which had not been required to put aside capital reserves as a cushion for the protection it was selling, was bailed out when it could not meet its obligations. The government ultimately committed more than \$180 billion because of concerns that AIG’s collapse would trigger cascading losses throughout the global financial

system. In addition, the existence of millions of derivatives contracts of all types between systemically important financial institutions—unseen and unknown in this unregulated market—added to uncertainty and escalated panic, helping to precipitate government assistance to those institutions.”

The Financial Crisis Inquiry Commission also commented that the regulators had the power to protect the financial system from the diffusion of the crisis. In their view, the Securities and Exchange Commission (SEC) could have required more capital and stopped risky practices of the big investment banks. The Federal Reserve Bank of New York could have prevented excessive leverage of major financial institutions, such as Citigroup. Also, policy-makers and regulators could have stopped the widespread practice of mortgage securitization. Instead, regulators authorities did not act, for reasons that may be related to a lack of political will and to cognitive and social barriers to criticize the way the financial system operated, especially in an age when finance seemed (to the eyes of many, including those in public and supervisory authority positions) to support growth and profitability.

Chapter 4

The Regulation of OTC Derivatives

4.1 Financial Regulation: An Overview

The regulation of the financial system consist of activities that are carried out by public and supervisory authorities on the conduct of financial institutions in order to maintain the integrity of the financial system. Financial regulation is concerned with the solidity of individual financial operators, the protection of financial customers, the maintenance of confidence in the financial markets, and the stability of the financial system as a whole. These aims are attained through various means, which include the provision of guidelines and standards of conduct (i.e., a ‘soft regulation’) and the enforcement of requirements and restrictions on the behavior of financial operators. These activities are carried out by several supervisory and regulatory authorities (with some variations across countries), which generally focus on the supervision of stock markets, of derivatives markets, of listed companies, and of banks and other financial operators (e.g., dealers, brokers, and market-makers). In the US, for example, regulatory institutions include the Securities and Exchange Commission (SEC), the Financial Industry Regulatory Authority (FINRA), the Commodities Futures Trading Commission (CFCT), the Federal Reserve, and other public and supervisory agencies. In the UK, regulatory functions are performed by the Financial Conduct Authority (FCA) and the Prudential Regulatory Authority (PRA). In Italy, financial regulatory functions are carried out by the *Commissione Nazionale per le Società e la Borsa* (CONSOB) and the Bank of Italy.

A large component part of financial regulation is the regulation of banks, which obviously play a fundamental role as financial intermediaries that borrow funds, lend funds, and operate in the financial markets. Bank regulation is intended to attain various objectives, including preserving the financial solidity of individual banks, reducing systemic risk, avoiding misuse of funds and fraudulent behavior. Regulation of banks is carried out through various means, that generally include supervisory activities (e.g., the issue of a bank license before the financial institution can operate), minimum requirements (e.g., setting conditions, such as minimum capital ratios, that banks have to comply with), and

market discipline (e.g., stock market's reaction to public information provided by banks when complying with mandatory disclosure requirements). In part, these regulatory approaches - called the 'three pillars' under Basel II - are implemented through various tools, such as, for example, reserve requirements, credit rating requirements, corporate governance regulations, financial reporting and mandatory disclosure requirements, and various kinds of restrictions (such as, for instance, mandatory separation of commercial and investment banking activities, that was provided in the US by the Glass-Steagall Act in 1933).

Among the tools of banking regulation, capital requirement is especially relevant in the context of the present discussion on derivatives regulation. In general terms, capital requirement relates to the amount of capital that a financial institutions must hold as required by the financial regulator, generally expressed as a percentage of risk-weighted assets. Since the late 1980s, capital requirement has been determined on the basis of the Basel Accord, namely by Basel I in 1988, Basel II in 2004, and recently, Basel III in 2010-11. Basel I, which was eventually adopted in over 100 countries, provided a classification of assets into five categories depending on credit risk and required banks to hold capital equal to 8% of risk-weighted assets. Basel II defined capital requirement in relation to three kinds of risk, namely credit risk, operational risk, and market risk, and provided specific methodologies for calculating each of them (although also Basel II provided that banks could progressively develop their own risk measurement system in place of standardized approaches). Basel II defined two types of capital, namely 'tier 1' largely formed of shareholders' equity and disclosed reserves and 'tier 2' (or supplementary capital) formed of undisclosed reserves, revaluation reserves, general provisions, hybrid instruments and subordinated term debt, and required banks to comply with set ratios of tier 1 and tier 1+2 capital with respect to risk-adjusted assets.

Basel III, which was negotiated in the aftermath of the Great Financial Crisis in 2010-11, developed within the context of the policy reactions to deficiencies in financial regulation. In general terms, Basel III strengthens the capital requirements principles already set by Basel II, while it also introduces additional forms of safeguard to financial stability. Basel III provides that minimum common equity would be raised to 4.5% of risk-weighted assets after deductions; that contractual terms of capital instruments would include a clause that allows – at the discretion of the relevant authority – write-off or conversion to common

shares if the bank is judged to be non-viable; that banks should hold a capital conservation buffer that includes common equity equal to at least 2.5% of risk-weighted assets (bringing the total common equity standard to 7%); and that banks should set up a countercyclical buffer within a range of 0-2.5% comprising common equity, when authorities judge credit growth is resulting in an unacceptable build up of systematic risk.

Basel III also contains measures intended to provide risk coverage and contain leverage. Measures include the strengthening of capital treatment for certain complex securitization and the requirement that banks conduct more rigorous credit analyses of externally rated securitization exposures; the requirement that banks hold significantly higher capital for trading derivatives, as well as complex securitization held in the trading book; the introduction of a stressed value-at-risk framework to help mitigate pro-cyclicality; the introduction of a capital charge for incremental risk that estimates the default and migration risks of un-securitized credit products and takes liquidity into account; the strengthening of the counterpart credit risk framework with more stringent requirements for measuring exposure, incentives for banks to use central counterparts for derivatives, and higher capital for inter-financial sector exposures. Basel III also provides that trade exposures to a qualifying CCP will receive a 2% risk weight and default fund exposures to a qualifying CCP will be capitalized according to a risk-based method that estimates risk arising from such default fund. Finally, Basel III also provides a non-risk-based leverage ratio that includes off-balance sheet exposures and that serves as a backstop to the risk-based capital requirement.

Within the Basel III capital requirements, special attention has been devoted to the regulation of systemically important financial institutions (SIFIs). Basel III provides that SIFIs must have higher loss absorbency capacity to reflect the greater risks that they pose to the financial system. By using a methodology that includes 12 indicators of both quantitative and qualitative sort to identify systemically important banks, the requirement provides that banks increase their loss absorbency requirements with a progressive Common Equity Tier 1 (CET1) capital requirement ranging from 1% to 2.5% depending on the bank's systemic importance. Additional loss absorbency plays the role of disincentive to increase a bank's global systemic importance. Notably, after the initial release of the higher loss absorbency capacity requirement by the Basel Committee on Banking Supervision in November 2011, a revised document - titled "Global systemically important

banks: updated assessment methodology and the higher loss absorbency requirement” - was issued in July 2013.

Basel III also contains additional provisions that refer to leverage ratio and to liquidity requirements. The leverage ratio is specifically intended to counteract the effects of too high leverage in financial institutions. During the Great Financial Crisis, market pressures induced highly leveraged financial institutions to de-leverage, with the effect of pushing asset prices down even further. This de-leveraging amplified the feedback loop between losses, reduction of bank capital, and reduction of credit availability. Basel III introduced, therefore, a non-risk based leverage ratio (computed as the ratio between capital measure - or Tier 1 capital - and exposure measure - largely based on accounting data but also taking into account of off-balance-sheet items) as an additional cautionary measure to the risk-based capital requirement. The introduction of leverage ratio is still in progress, and it is expected to be fully implemented by 2018.

Finally, the liquidity requirements of Basel III are intended to provide additional sources of resilience of the financial system. The liquidity requirements take the form of the Liquidity Coverage Ratio (LCR) and the Net Stable Funding Ratio. The Liquidity Coverage Ratio aims to make a bank retain enough high-quality liquid assets to cover its total net cash outflow over 30 days in stress scenario, while the Net Stable Funding Ratio aims to make the available amount of stable funding to exceed the required amount of stable funding over a one-year period of extended stress. It is the LCR that is especially keyed to ensure the liquidity in face of potential stress in the short term and to avoid potential spillovers from the financial to the real sectors of the economy (BIS, 2013). In essence, the LCR provides that banks retain an adequate amount of high quality liquid assets. The requirements of the LCR will be introduced at reduced intensity (60% by 1st January 2015) and they will progressively increase over time until full implementation by 2019.

It should be highlighted that the flow of regulatory interventions - from Basel I to Basel III - follows an evolutionary trajectory. Basel I regulations primarily addressed credit risk, while other kinds of risks were left to the national regulators. Also, Basel I primarily targeted globally active banks, and it was intended to reduce global competitive inequality among banks and to strengthen the international banking system (Balthazar, 2006). Basel II regulations were intended to address some shortcomings of Basel I, especially in face of

emerging securitization activity of banks and of the development of internal models for risk assessment in large banks (that had become more complex and sophisticated than the one provided in Basel I). Basel III regulations emerged as a prompt response to the Great Financial Crisis and were aimed to increase the safety of the banking system, with special attention to liquidity management.

Some, however, contend that the regulation of the financial and banking system followed an evolutionary approach. Cunningham and Zaring (2009), for example, highlighted that a noticeable feature of the present financial regulatory system that emerged from the response to the Great Financial Crisis is that the reform of the financial and banking system followed a ‘developed-on-the-fly’ approach, i.e., that regulations consisted of scattered and reactive measures taken to counteract urgent problems rather than of a well designed and comprehensive program of interventions. This characterization of the present regulatory system would be especially apparent in the US, where the initiatives of Secretary of Treasury Henry Paulson and Federal Reserve Chair Ben Bernanke in 2008 converted a previously disaggregated domestic financial and banking regulatory regime into a more centralized one. The resulting US regulatory system granted more relevance to the central bank, created a de facto hierarchy of financial regulators, marginalized the role of investment banks, and federalized or nationalized other firms. Incidentally, Cunningham (2009) also argued that the present US regulatory system, devised along Paulson’s intentions, is one where consolidation serves the purpose of enhancing the global competitiveness of the US financial system, in contrast to a more internationally collaborative approach as could have developed under Paul Volcker’s orientation.

4.2 Weaknesses and Limitations of the Present Financial Regulatory System

Several studies have tried to assess the strengths and weaknesses of financial regulations. A review of some among the main works done in this area is important in order to articulate the rationales and objectives of financial regulation. In addition, a review of these works also serves the purpose of explaining the arguments for the identification of the ‘open issues’ in the regulation of the financial system at the present time. The construction of a safe and sound regulatory system - especially, one that takes into account the apparent need for greater macro-prudential regulation - is still an unfinished work, and - as we will argue below - additional research is needed to enhance the resilience and solidity of the financial

system worldwide. Generally speaking, works done on the assessment of the strengths and weaknesses of financial regulation can be divided in two camps, namely those that advocate for the need of a better designed regulatory system and those that argue that regulations have negative or counter productive effects and that they should be reduced or minimized (that Basel III financial regulation would result in negative effects, moreover, was also argued by bankers and top executives, who claimed that that the increased capital ratios would make banks to able to function and would reduce banks' return on equity with detrimental effects to their shareholders).

Brunnermeier et al. (2009) are among those who argued that additional attention should be paid to designing better financial regulation. After noticing that financial and banking crises are not too rare phenomena (e.g., they counted more than 100 such crises before the 2007-08 one), they highlighted the main rationales for regulation of financial activity, that relate to the presence of five kinds of negative externalities:

1) *Information contagion*: the failure of a financial institution generates beliefs that also other (similar) financial institutions may default, with the effect that lenders of other financial institutions lose confidence and withdraw their funds, causing a sudden liquidity problem for the other financial institutions and resulting (in a self-fulfilling prophecy) in a more likely default.

2) *Information loss*: the failure of a financial institution results in the difficulty for the customers to access funding from other financial institutions, which do not possess the detailed information that the defaulted financial institution possessed about the customers.

3) *Loss contagion*: in nowadays economy financial institutions are deeply dependent upon reciprocal lending and risk-shifting schemes, therefore the failure of a financial institution is likely to have repercussions in terms of losses of other financial institutions.

4) *Liquidity spirals*: liquidity difficulty in one financial institution may trigger forced sell of assets (fire sales), that result in the fall of market prices of the same assets held on other financial institutions' books, with the effect of worsening the solvency and liquidity of these other financial institutions (that, in turn, may trigger further forced sell of assets).

5) De-leveraging: liquidity difficulty in one financial institution may also trigger the restriction of credit extension to borrowers, with the effect of lowering output and prices in the economy, therefore increasing the likelihood of defaults of borrowers (that, in turn, may trigger further restriction of credit extensions).

Brunnermeier et al. (2009) argued that in the past financial regulation was overtly focused on the conduct of individual banks (i.e., it was too much micro-prudential) and that it has therefore overlooked the problem of negative externalities spreading from one financial institution to another (i.e., regulation should be more macro-prudential). The authors suggest, however, that it is the self-amplifying dynamic (e.g., contagion or repercussions of one financial institution's default or liquidity problems onto other financial institutions) that lies at the core of financial crises. In fact, while the maturity mismatch between assets and liabilities at any particular financial institution may be relatively contained, at the systemic level the concatenation of lending relationships between financial institutions may result in an overall serious mismatch that may capitulate into sudden liquidity problems.

In the past, financial regulators had largely assumed that if financial institutions had adequate capital ratio then they could avoid illiquidity problems because of the possibility to raise extra funds in the market. Evidence from the Great Financial Crisis showed that this is not always the case. Illiquidity problems may arise anyway, especially in relation to the aggregate ('herding') behavior of financial institutions. If something the Great Financial Crisis made clear, therefore, it is that micro-prudential regulation (one that has been historically linked especially to capital adequacy) should be complemented by macro-prudential one for safeguarding the financial system as a whole. The macro-prudential approach should be based on measures to counteract the cyclicity of the economy and to penalize dangerous funding mismatches.

Several academic works have called for the design of better financial regulation. Laeven and Levine (2008) noticed that capital requirements may induce increasing risk taking, as the owners of the financial institutions tend to compensate for the loss of utility from more stringent capital requirements by selecting a riskier investment portfolio (Koehn and Santomero, 1980). Kashyap et al (2010) highlighted that increased capital requirements result in the migration of credit creation to the shadow banking system, that can enhance the fragility of the financial system, and that therefore financial regulation is incomplete if

the shadow banking system is not included in regulatory supervision. Vallascas and Kaesey (2012) highlighted that, while capital adequacy and liquidity requirements may improve the resilience of a bank to systemic events, a cap on bank absolute size appears the most effective tool to reduce the default risk of a bank given systemic events, and that smaller economies would require smaller banks.

Acharya (2009) argued that we should take a 'collective' approach towards financial regulation, where regulators should be concerned with the joint failure risk of banks as well as their individual failure risk. In effect, every bank makes investment choices that have externalities on the payoffs of other banks and others' investment choices. Regulators, therefore, should take into account how banks behave taking into consideration the incentives that arise from financial regulation and the consequences of the conduct of other financial operators. The design of regulatory policies that takes into account only individual bank risks is suboptimal in a multiple bank context. Capital adequacy requirements, in particular, should be increasing in the correlation of risks across banks as well as individual risks. Moreover, banks should be penalized for holding portfolios with high correlation of returns, therefore the author proposed a 'correlation-based' capital adequacy requirement.

Brunnermeier et al. (2009) noticed that, although small financial operators may not pose any systemic risk, they may exhibit 'herding behavior', i.e., they may conduct investment choices in a similar way so that their aggregate effect is the one to take considerable amount of overall risk. If this is the case, then not only do regulatory authorities need to monitor the conduct of financial operators (i.e., to require transparency), but they also need tools to affect the behavior of financial operators in order to prevent, or to correct, the excessive concentration of risk in the financial system (Blinder, 2010). It seems appropriate, then, that the regulatory system provides that higher capital requirements are placed on systemically important institutions, whose potential impact on the rest of the financial system relates to their size and structure of network relationships (moreover, the additional capital charge would be justified by their 'too big to fail' substantive status, that entails the likelihood that public authorities would step in to rescue them from default). Additionally, we could consider whether also any other financial operator should be required to hold additional capital depending on how much they contribute to systemic risk in the financial system.

Blinder (2010) highlighted that the proposal to require financial institutions to hold additional capital in relation to their particular relationship to systemic risk builds on the notion of ‘contingent capital’, akin to the function of ‘reverse convertible debentures’ (Flannery, 2005). The proposal entails that regulators would have the power, by declaring a systemic crisis, to force holders of special convertibles to convert bonds to equity against their will. In this way, financial institutions would be given more equity capital and less debt when they need it. These special convertible bonds would call for higher interest rate (because of the diminished value of being subjected to compulsory conversion; else, the conversion rate could be priced below market). A limitation of the proposal, however, is that it is hard to anticipate how much the market would price these special convertible bonds and how costly they would be, as source of capital, to financial institutions. This proposal has been also made by the Liikanen Report (2012), which exactly called for greater use of ‘bail-inable debt’.

De Lisa et al. (2011) focused on deposit insurance schemes and proposed a new approach of estimating the loss distribution based on Basel II framework. By considering two major sources of systemic risk, namely the correlation between banks’ assets and interbank lending contagion, they showed that the introduction of bank contagion via the interbank lending market could lead to the collapse of the entire banking system of a country (they especially focused on the empirical basis of Italian banks). They argued, therefore, that policy-makers should reconsider capital requirements in relation to deposit insurance schemes.

Acharya et al. (2011) reviewed the contrasting tendencies that operate on the debt-to-equity structure of financial institutions. They proposed that banks should hold a two-tier capital framework, that includes first tier of regular core capital requirement that is intended to deter excessive risk-taking, and a second tier of special capital account that limits risk taking but preserves creditors’ monitoring incentives. The second tier of special capital account consists of capital that must be invested in Treasuries or equivalent, which would belong to the shareholders as long as the bank is solvent, and to the regulators if the bank defaults. In this way, it is possible to reduce the risk-appetite of banks and to monitor bank manger (which would also care about the share of debt that could be converted to equity).

Hanson et al. (2011) reviewed the mechanisms of macro prudential policy, and recommended that financial regulatory regimes should include additional tools to ensure the stability of the financial system, namely: time-varying capital requirements (where banks are asked to maintain higher ratios of capital to assets in good times than in bad times in order to rely on a buffer when adverse shocks hit and have less capital requirement pressure when a crisis erupts); higher quality capital (where banks should be rapidly recapitalized in a crisis, and therefore regulators should require most capital requirement to be satisfied with common equity rather than preferred stock); corrective actions taken as dollars of capital, not capital ratios (where banks would be required to raise additional capital until they repair their capital ratios); contingent capital (where banks would be required to hold instruments of automatic recapitalization when some conditions - related to crisis events - are triggered, like automatically convertible bonds); regulation of debt maturity (where banks would be required to hold more longer term debt); and regulation of shadow banking (where regulators should also focus on non-bank financial operators, which do not finance themselves with insured deposit but which are nevertheless subject to wholesale financial runs).

Levine (2012) argued that financial regulation may not be so relevant to prevent or contain financial crises if these are fundamentally triggered by bad policies. In the author's opinion, the seeds of the Great Financial Crisis lay in the deliberate and ill-fated policies that policy-makers - notably, the US Congress and the Federal Reserve - pursued and that resulted in encouraging financial markets and financial institutions to take excessive risk (Levine, 2010). In Levine's (2012) view, then, financial regulation is 'missing the point' when it focuses on tools of micro-prudential and macro-prudential regulation, as the crises may be rather fueled by defects in systemic financial governance. In other words, regulatory requirements are not able, by themselves, to counteract the negative effects of bad policy decisions made by policy-makers and regulators, who should be, because of their expertise and position, able to anticipate the consequences of their choices. Levine (2012), therefore, argued that the financial regulatory system is missing the mechanism through which the public and its elected representatives can obtain an informed, expert, and independent assessment of financial regulation. That the reform of the financial system did not place adequate attention to governance was also noticed by Avgouleas et al. (2013), who highlighted the lack of formal governance structure dealing with cross-border supervision

of global financial institutions and with cross-border crises and resolution of global institutions.

Other academic works, instead, can be placed in the camp of those who argued that regulations have negative or counter productive effects and that they should be reduced or minimized - rather than enhanced. Van Hoose (2007), for example, held that the intellectual foundations for the capital regulation regime is not too strong: according to reviewed literature, the effects of capital regulation on asset risk and overall safety and soundness of the banking system may be not so clear, as increased capital requirements may enhance bank stability but they may also make banks riskier institutions. He also noticed that, drawing from the implementation of Basel I, past experience suggests that financial operators can learn how to 'game the system' and substantially bypass unwelcome regulation. Also, greater capital requirements result in a reduction in total lending, increases in market loan rates, and substitution from lending to holding alternative assets. In sum, van Hoose (2007) presented some skeptical arguments for the effectiveness of capital requirements, provided that, although they may result in greater capital cushion from losses, they may also induce banks to adjust their behavior in ways that result in counterproductive effects.

Another work in this camp is the one of Thakor (2012), who especially criticized the so-called 'Volcker rule', i.e., a ban on proprietary trading (investment banking) by commercial banks included in the 2010 Dodd-Frank Act. Thakor (2012) argued that the Volcker rule has negative effects on market making and liquidity provisions for many securities, making financial institutions focus on smaller and riskier securities where large and unexpected supply-demand shocks are more likely. Also, the Volcker rule would reduce the network benefits of market making for financial institutions and businesses, it would result in higher cost of capital for businesses and lower capital investment by borrowers, and it would make bank risk management less efficient, harming the ability of businesses to raise capital.

Among the works that criticize the present financial regulatory system, Scott (2010) highlighted that the capital requirements for containing systemic risk should be determined by market forces rather than by regulators. The author noticed that the Basel process had attained a rather poor record to prevent or contain financial crises, for reasons that he imputes to the methodological and political difficulties in the group of regulators. Rather

than determining capital requirement on administrative basis, then, he proposed that financial institutions should be required to disclose their risks and that they should not be provided any bailout (in order to reduce moral hazard): accordingly, creditors and counterparts should become more vigilant in assessing the riskiness of financial institutions for both the particular transactions and for the threat that they would pose to the financial system.

The argument that market forces are able to provide discipline to financial institutions in particular and to the financial system as a whole in general was also put forward by other scholars, including Dowd (1996). If there is no lender of last resort or government guarantees, depositors and investors would be aware of the risks, and therefore would be attentive to screen less risky banks, monitor bank behavior, and withdraw their funds at the earliest sign of misconduct. In order to avoid funds withdrawal, financial institutions would be inclined to pursue conservative lending and investment policies and to enhance their transparency to reassure depositors and investors. Among the measures that financial institutions would take to signal their quality, they would self-select levels of capitalization that better satisfy the market demand from depositors and investors.

Of course, such argument for market-based regulation of the financial system is criticized on various grounds. Dowd (1996) argued that market-based regulation of the financial system would be extremely pro-cyclical and that the central bank would intervene in any case. Santos (2001) highlighted that financial institutions play such an important role in financial intermediation as providing liquidity, monitoring and information services that any systemic crisis would entail intolerable social costs. Moreover, market-based regulation would not completely remove the moral hazard problem, provided that the managers of financial institutions would not necessarily behave in a way that is consistent with the interests of the owners (and of the depositors and investors alike). In addition, screening and monitoring is too costly for any single depositor or investor, especially smaller ones. If any depositors or investors engage in screening and monitoring, then others would free ride taking advantage of others' efforts to extract relevant information and simply mimic their behavior.

Arguments that criticize the present financial regulation may also relate to either ideological or partisan perspectives. As a matter of pragmatism, the present financial

regulation is largely intended to address the fundamental issue of commercial and financial relationships, namely hidden leverage (Simkovic, 2009). Hidden leverage refers to the problem where debtors have the interest to hide their debts in the eyes of creditors: higher leverage, in fact, entails that debtors are perceived more risky and therefore would be charged higher interest rates for additional debt. In principle, it would be beneficial for all (potential and actual) creditors to share information about transparent (potential and actual) debtors, so that they are equally well informed of the creditworthiness of the debtors. In practice, debtors and creditors may collude to hide the borrowing already made to other potential lenders and to grant a preferential treatment to loans already in place: in this way, existing senior creditors would be privileged with respect to novel junior ones in case of default, and the debtor would not have to pay higher interest rates to the novel junior creditors.

In the past, commercial and financial law generally developed the doctrine of so-called 'secret lien'. A lien - that is, a claim of a creditor on the debtor's property that is superior to claims of other creditors - is secret if it is not properly disclosed to other potential creditors. The doctrine of 'secret lien' states that secret lien holders do not have any preferential treatment in case of debtor's default, and that their claims are rather subordinated to those of other creditors. The doctrine of secret liens, therefore, deprived hidden leverage of a source of legal protection and therefore stimulated transparency. Over the last century, however, the doctrine of secret lien has been progressively eroded by various policy measures, that gradually introduced various forms of exceptions to bankruptcy codes and exemptions from the rule. A very relevant policy change, in this respect, was the introduction of an exception to the secret lien doctrine granted to asset securitization and derivatives, i.e., the granting of preferential treatment to the holders of asset-backed securities and derivatives even if these financial contracts did not comply with transparency requirements (i.e., de fact, they allowed the formation of hidden leverage that could not be monitored and assessed to the eyes of other creditors). Simkovic (2009) argued, in fact, that it was exactly the preferential treatment granted to asset-backed securities and derivatives (i.e., the presence of liens attached to these financial instruments in case of default of the debtor) that account for their diffusion and growth in the financial system, especially in the last few decades (Faubus, 2010).

One central feature of Basel III and of national legislations passed in the aftermath of the Great Financial Crisis, like in the US, is precisely the one to acknowledge that more transparency is needed in order to enable financial operators and regulators to better understand the leverage and the exposure to risk of financial institutions. This and other financial regulations, such as greater capital requirements and limitations of universal banking, will result in profound changes to the business models and the strategies pursued by financial institutions (Weingher, 2012). According to Weingher (2012), it is likely that low-margin businesses will be reduced, capital will be increased in both US and EU financial institutions, and profitability will decrease, making the financial industry less attractive for investors (and also inducing banks to pursue cost cutting policies). Probably banks will have to reduce the size of their balance sheets to meet the required capital ratios, at least in the short run. Also, managers may be especially concerned to meet short term regulatory requirements rather than caring about the long term strategic development of the financial business. Finally, the new liquidity requirements may lead to a ‘race for deposits’ where banks will start and target sources of liquidity funding (e.g., pension funds, insurers and mutual funds) in competition between each other and other financial operators.

Finally, it should be highlighted that additional proposals to address some limitations of the emerging financial regulatory system have been put forward, within the EU, by the so-called Liikanen Report (2012). The Report especially recommended five measures to complement the regulations already in place: first, that proprietary trading and other significant trading activities should be assigned to a separate legal entity if they amount to a significant share of a bank’s business (i.e., a principle similar to ‘Volcker’s rule’ in the US); second, that banks should draw up effective and realistic recovery and resolution plans; third, banks should start making use of ‘bail-inable debt’, i.e., obligations (bonds) that are converted into equity against the will of the holders in case of trouble (e.g., presence of a systemic crisis); fourth, that more robust risk weights should be used in the determination of minimum capital requirements; lastly, that corporate governance of financial institutions should be improved, including measures for strengthening boards and management, enhancing risk management, limiting compensation for bank management and staff, improving risk disclosure, and strengthening sanctioning powers.

4.3 The Regulation of OTC Derivatives

Regulation of derivatives has been long debated within academic circles. Cohen (1994) observed that at least three frameworks for derivatives regulation existed. The first one consisted of a system of voluntary compliance by dealers (a preferred non-interventionist method followed in the US in the 1980s and 1990s). The second one provided the inclusion of derivatives regulation within the general framework of securities regulation, although the legal nature of derivatives differs from the one of shares, bonds, and other securities. The third one was to admit that derivatives regulation required special legislation on its own. Over time, concerns that derivative trading was booming but that it fundamentally remained without any well designed regulatory framework led scholars to argue for regulatory interventions (Romano, 1996). Still in the 1990s, regulation of derivatives could be summarized in two basic requirements (Hentschel and Smith, 1996):

1) Capital adequacy rule: general capital requirements set for banking activity were applied also to derivative trading, although originally they had not been designed specifically for the purpose of regulating the trade of derivatives. Following a model developed by BIS, capital was required in proportion to the credit-equivalent of the exposure to derivatives. The requirement, however, did not take into consideration whether the counterpart was hedging or exacerbating their exposure, nor the leverage in the transaction, nor the diversification or concentration of risks related to derivatives positions.

2) Disclosure requirements: generally, financial operators that traded in derivatives only applied general accounting rules, that did not provide adequate disclosure for the purpose of monitoring and assessing counterpart risk, nor for the one of supervising systemic risk.

As financial innovation progressed and the volume of the derivative market grew, it became apparent in the 1990s that the system of regulation of derivatives was inadequate. In 1998, the CFTC, led by Ms Brooklyn Born, issued the “Over-the-Counter Derivatives Concept Release”, that aimed to call a wide class of derivatives under the regulatory influence of the agency. The Release was unwelcome by the financial industry and part of the US government system, which counteracted by impressing a dramatic turn towards the liberalization of the derivative market with the Commodity Futures Modernization Act of 2000 (CFMA) (Lynch, 2011; Baker, 2009). The CFMA confirmed that certain OTC derivative trades were outside the jurisdiction of the Commodity Futures Trading

Commission (CFTC) and, de fact, provided that all financial derivatives are legally enforceable (Stout, 2011). This provided legal certainty to OTC derivative transactions and shielded them from regulatory interference (D'Souza et al., 2009). Following the CFMA, the volume of transaction in OTC derivatives that had been placed outside CFTC regulatory increased rapidly, together with faster pace of financial product innovations. It may be worthy noticing that, despite strict regulatory requirements, at that time public authorities seemed to believe that the derivative market was under adequate supervision. As a report of the US Government Accountability Office stated:

“Because OTC credit derivatives transactions [or any OTC derivative transaction, for that matter] occur between private parties and are not traded on regulated exchanges, they are not subject to regulation in the United States, provided that the parties and other aspects of the transaction satisfy requirements of the Commodity Exchange Although the OTC credit derivatives products themselves are not regulated, certain market participants are. If the dealer is a U.S. bank federally chartered as a national bank, it is supervised by the OCC [Office of the Comptroller of the Currency]. If a bank is owned by a bank holding company, its holding company is regulated by the Federal Reserve. These bank regulators oversee these entities to ensure the safety and soundness of the banking system and the stability of the financial markets. If the credit derivatives dealer is a securities broker-dealer, it is overseen by SEC. According to U.S. regulators, some of the U.S. banks and securities broker-dealers also conduct credit derivatives trades in foreign affiliates subject to foreign regulation. Similarly, other participants in the credit derivatives market include foreign banks that are supervised by foreign regulators and, in some cases, also by U.S. regulators if operating in the United States.”

Within the new regulative framework that emerged in the aftermath of the Great Financial Crisis, a special place is taken by the regulation of OTC derivatives (Pagliari, 2012, 2013; Duff and Zaring, 2013). Following the 2009 G20 meetings, initiatives to reform the regulation OTC derivatives took off at both the national and super-national level. At the international level, a review of OTC derivatives regulation and proposals for reform were conducted by the OTC Derivatives Coordination Group, formed by the chairs of the Financial Stability Board (FSB), the Basel Committee on Banking Supervision (BCBS), the Committee on the Global Financial System (CGFS), the International Organization of

Securities Commissions (IOSCO) and the Committee on Payments and Market Infrastructures (CPMI). At the super-national level, specifically in the EU, OTC derivatives came to be regulated by so-called European market infrastructure regulation (EMIR), i.e., Regulation (EU) 648/2012, that came into force on 16th August 2012. In the US, the 2010 Dodd-Frank Act provides, in Title VII, a comprehensive framework for the regulation of OTC derivatives (swaps).

The contemporary regulation of derivatives is set to address three primary issues (Acharya et al., 2009):

- a) uncertain counterpart credit risk exposure, which can generate illiquidity and can cause markets to break down;
- b) capital erosion, which can cause the financial system to break down if the erosion is large and it is concentrated in financial institutions that provide liquidity to part of the financial system;
- c) prices that may be away from fundamentals due to illiquidity of the market, as it may originate from fire sales, and which can cause distortion in capital allocation decisions.

Generally, greater transparency is a requirement that can help coping with these issues, especially counterpart credit risk, but it can also generally serve the purpose of monitoring the building up of risk exposures that can be systemically relevant. Before the regulations set in the aftermath of the Great Financial Crises, regulators did not have tools for monitoring the build up of exposure risk at their disposal. Accordingly, works like the one of Acharya et al. (2009) proposed that issues of derivatives regulation could be effectively dealt with by using a central clearing house or exchange structure for monitoring counterpart risk externalities (but also with appropriate collateral and margin requirements) or at least centralized registries for tracking transactions; by letting regulators, clearing houses, exchange market structures and registries access all relevant information about derivative trading and risk positions in a timely manner (also, some transparency for the public of trade-level information on volume and prices in real time, albeit without revealing identities of the traders); and by introducing information requirements and oversight on derivatives in a way similar to other stocks and securities (i.e., differently from the unregulated regime for many OTC derivatives that took place in the last decades).

Several other scholarly works highlighted the importance of the kind of regulatory tools indicated in Acharya et al. (2009) (Duquerroy et al., 2009; Barnier, 2010; Garicano and Lastra, 2010; Hull, 2010; Barr, 2011; Singh, 2011; Flood et al., 2012; Duff and Zaring, 2013). Ngo (2007) argued that the system of CCP could be helpful to reduce the complexity of the network of derivative contracts, by establishing a kind of ‘hub-and-spoke’ configuration. Of course, the CCP should be adequately robust, in order to prevent it becoming a source of financial loss or liquidity shortage contagion by itself. The CCP can also help reducing the volume of derivative positions (and, relatedly, of margins and guarantees) by assisting the ‘netting’ of derivative contracts, i.e., clearing reciprocal and equal (albeit of opposite sign) obligations between counterparts rather than having counterparts mutually exchanging equal amounts of cash flows (in principle, moreover, netting can also take place between more than just two mutually trading counterparts, if sophisticated multi-lateral netting algorithms are employed on the basis of the information on multiple derivative contracts collected by the CCP).

Also Cecchetti et al. (2009) argued that a CCP for OTC derivatives can improve market resilience by lowering counterparty risk and increasing transparency. The transfer (or ‘novation’) of the derivative contract between two parties to the CCP (in practice, the replacement of the derivative contract with two contracts written between each of the counterparts and the CCP) entails that the CCP can net multilaterally and therefore reduce both counterparty and operational risk, increase the efficiency of collateral management, and ensure consistent mark-to-market evaluations of exposures. CCP should be provided with adequate capital (typically in the form of fees from members) and keep liquidity position. CCP would improve transparency by allowing collection of high-frequency market-wide information on market activity, transaction prices and counterparty risk exposures for market participants. The effect of CCP on pro-cyclicality of derivatives (i.e., the requirement to post additional collateral as risk increases and the effect on liquidity) is uncertain: in principle, CCP can reduce pro-cyclicality by lowering counterparty risk but, on the other hand, centralized margin calls could aggravate pro-cyclicality.

Also Kiff et al. (2009) argued about the benefits of CCP. They highlighted that a CCP can act as intermediary for exchange-traded derivatives by catching the trade information automatically in real time from the trading platform and becoming the direct counterpart after trade execution. For OTC derivatives, however, the CCP should be informed of the

conditions attached to the negotiated derivative contracts. In addition, the authors also highlighted the importance of the structure of the CCP industry, especially that, while competition between different CCPs may be beneficial, the efficiency of counterparty risk mitigation produced by CCP decreases as the number of CCPs clearing the same product type increases (Duffie and Zhu, 2009). Also, the CCP industry builds on network externalities, so that net benefits from the use of CCPs is evident when a relatively high number of members join the scheme, and scale economies, so that average cost per transaction declines with an increase of the number of transactions (especially because of the high fixed costs of the derivatives clearing IT infrastructure). It is possible, therefore, that the structure of the CCP industry is relatively consolidated, with the effect that CCP firms would be subjected to regulation (as any public utility). Public authorities, therefore, will play an important role in the conduct of the CCP business, especially because failure of a CCP would seriously affect the functioning of the entire financial market.

Baker (2009) argued that, in addition to increase prudential supervision and regulation, the regulation of OTC derivative markets requires domestic and international systems for regulatory cooperation, i.e., within the US, there should be cooperation between SEC and CFTC (a 'regulatory joint venture'), and, internationally, there should be a system of public-private partnership to coordinate regulation in the global marketplace. The author questioned the effectiveness of regulatory systems that divided the competences between regulatory agencies (as this could leave room for unregulated kinds of derivatives), of the conventional division between standardized and non-standardized derivative contracts (as this has been difficult to implement in the past, because of the flow of innovative derivative products that did not plainly fit any classification), and of the lack of attention for international aspects of regulation of derivatives, that are nowadays often traded in global markets. Baker (2009) argued that disclosure of OTC contracts is pivotal to facilitate the monitoring of the systemic risk entailed by derivative positions, but regulators lack both current and past data.

As highlighted by Cherny and Craig (2010), a CCP or clearinghouse would help regulating derivatives by making it possible to absorb the default of a financial institution, rather than letting the consequence of the default propagate to other financial institutions in a potentially escalating effect. The clearinghouse would work through two main tools, namely contract standardization, that would make valuation easier by removing

heterogeneous terms and increasing trading volume, and margin enforcement, that would protect the clearinghouse from counterparty default (the margin would be used to compensate the counterparty while protecting the clearinghouse from losses). The authors also highlighted that an exchange would also provide pricing services by soliciting bid and ask quotes from participants for standardized contracts.

Blinder (2010) highlighted the relative benefits of an exchange for derivatives, rather than a CCP or clearinghouse. Both kind of institutions provide mechanisms of central clearing, multilateral netting, greater transparency, and the imposition of a third counterparty between buyers and sellers that would help reducing counterparty risk. With respect to clearinghouses, however, an exchange would also provide regular public information about price and volume of traded contracts (although exchanges are typically opposed by dealers because they reduce their profits on spreads). In any case, Blinder (2010) also argued that any sort of regulation of the derivative market that enables monitoring counterparty and systemic risk would mark a significant improvement over the baseline of the pre-crisis, when derivatives regulation was substantially absent. The effectiveness of the Dodd-Frank Act, in this respect, was regarded as doubtful because of the many exceptions that it allows.

Duffie et al. (2010) observed that the working of the CCP or clearinghouse requires the charge of adequate margins on the members. The CCP should collect two types of margin: an initial margin, that is paid when the trade is cleared, and a variation margin, which is exchanged between the CCP and the member of the clearinghouse on a daily basis. The variation margin payment is the estimated change in the market value of the derivatives position from the previous day. In addition, members of the clearinghouse should provide the CCP with guaranteed fund, that is, an additional defense apart from initial margin to cover losses that originate from the failure of a member to perform on a cleared derivative.

Noyer (2010) highlighted that appropriate incentives should be designed to induce market participants to clear on CCPs. In this respect, regulators should find a balance so that collateral requirements are set not too tight (in order to make CCP clearing attractive) and not too low (in order to mitigate risk). The author noticed that not all derivatives can be cleared through clearinghouses or exchanges anyway (as many of them would remain unstandardized in any case), but efforts should be taken to move as many derivatives as possible into the CCP system. For those derivative contracts that are not placed in the CCP

system, regulators should ask market operators to implement appropriate risk management practices and higher capital requirements. This, of course, would also place some regulatory burden on market operators, which may lack - at present - the operational capabilities to deal with the new regulatory requirements.

It is worthy noticing that these arguments for the regulation of derivatives amount to a sharp difference from other positions, that rather believe that derivative markets possess self-regulating features. Long before the Great Financial Crisis, for example, Hentschel and Smith (1996) argued that counterparts of derivative contracts take great care of leaving little uncertainty about the nature and enforceability of the contractual obligations as they deem cost-effective, and that, in this sense, they should be able to design effective contract by themselves without the need for any regulatory intervention. In their view, deposit or margin requirements induce counterparts to take even more risk (i.e., more moral hazard problems) and evidence - until their time, of course - did not support the claim that derivative-related defaults, such as the one of Barings Bank in 1995, could escalate to systemic effects. Arguments about the futility, or even perversity, of regulating derivative markets have been reformulated along different lines, e.g., the inability of market operators and regulators to ‘digest’ and make sense the amount of information about derivative contracts even if they are subjected to mandatory disclosure (Bartlett, 2010; Best, 2010), the negative effects of tight regulation on financial innovation and the limitations of CCPs to manage default risk better than market participants (Gubler, 2011), and the stimulation that CCPs provide to take greater risks (Levitin, 2013). Others argue that there is no serious danger of a derivatives-induced financial collapse (Miller, 2011).

For the rest of the present discussion, we will especially focus on the EU regulation of OTC derivatives (there is a large amount of agreement between the EU and the US regulation of OTC derivatives; a detailed inquiry into the differences between the two regulatory frameworks, however, lays beyond the scope of the present work). The EU regulation of OTC derivatives (EMIR) builds on five main lines of interventions (Lannoo, 2011):

1) Reporting: EMIR requires all counterparts with outstanding derivative contracts to report details of these contracts to an authorized trade repository (TR). A TR (also called a Swap Data Repository) is an organization that collects and maintains records of OTC derivatives. This activity is carried out through an electronic platform that keeps records of

relevant contractual and economic information about OTC derivatives trades. At present, there are six TR registered (in 2013) by the European Securities and Markets Authority (ESMA), a EU financial regulator and supervisory institution that started operating on 1st January 2011.

2) Clearing: ESMA can impose mandatory clearing obligations for OTC derivative contracts once a central counterpart (CCP) has been authorized under EMIR for the type of contract. Clearing refers to the operations that are required in order to execute the derivative contract until the transaction is settled. A CCP is an organization that stands between two clearing firms with the purpose of reducing the risk of one or more clearing firms to fail fulfilling its contractual obligations, especially by requiring collateral (or margin) deposits, providing independent valuation of trades and collaterals, monitoring credit worthiness of the counterpart, and also providing guarantee that losses in excess of a defaulting firm's collateral are covered. In March 2014, Nasdaq Clearing became the first clearing house recognized under EMIR.

3) Non-cleared transactions: for those derivative contracts that are not cleared, all counterparts are required to comply with operational risk management requirements for the timely, accurate, and appropriately segregated exchange collaterals in order to reduce counterparty risk (a requirement generally called 'margining'). This requirement is applied to derivative deals with financial counterparts (i.e., banks, insurers, investment firms and fund managers, called FC) and with non-financial counterparts whose exposure in derivatives trading exceeds a certain threshold (called 'NFC+') (thresholds are set at different levels for credit, equity, interest, foreign exchange, and other derivative contracts). It is expected that the requirement will enter into force (with all detailed technical specifications) by the end of 2015.

4) Collateral: for those derivative contracts of financial counterparts, that are not cleared through a CCP, there will be the requirement that contracts are subjected to a bilateral collateral. The requirement is intended to reduce system risk (by reducing contagion and spillover effects) and to promote central clearing. The requirement, incidentally, also reinforced the need for international coordination and harmonization of derivatives regulation, provided that counterparts may be tempted to 'shop around' the most economically advantageous regulatory regime (and, relatedly, some country jurisdictions

may be tempted to engage in a ‘race to the bottom’ towards lighter regulatory requirements for attracting derivative deals).

It should be highlighted, that non-financial counterparts are subjected to derivatives regulations if their OTC derivatives positions exceed the thresholds set by EMIR (called ‘NFC-’).

In the past, derivatives in the EU had been regulated under Capital Requirement Directives (CRD) I, II, and III (issued in 2008, 2009 and 2010). CRD II and III, in particular, had provided incremental risk capital charges to reflect the risk of large but less frequent losses and the potential for large long-term cumulative price movements, and the requirement of calculate capital adequacy based on scenarios of longer periods of market losses. Later, CRD IV issued in 2013 (in force from 1st January 2014; also called Capital Requirement Regulation Directive or CRR) provided an additional capital charge for possible losses associated with the deterioration in the creditworthiness of a counterpart of a derivative (derivatives counterpart credit risk) (Liikanen, 2012). Further consideration, moreover, has been granted to the possibility to modify risk measures (from ‘value-at-risk’ to ‘expected financial shortfall’) to better capture ‘tail risk’ and to include elements of market illiquidity in the risk models (Liikanen, 2012).

Among the measures provided by EMIR and CRR, it is especially relevant the provision to collateralize and standardize OTC derivatives transactions by CCPs and to establish TR to collect information on non-standardized derivatives in order to increase transparency for regulators. Additional requirements, however, will be placed by the Markets in Financial Instruments Directive (MiFID) II, voted in 2014 and to come into force in 2017 (and to repeal MiFID I of 2004): MiFID II will provide that standardized derivative trades will have to be executed on exchanges and that the EMIR clearing obligation will be extended to exchange traded derivatives, although there will be still relevant exemptions for those entities that do not exclusively deal in derivatives on own account; there will be some regulation of limits on derivatives positions; and there will be stricter management and reporting requirements.

The going into force of EMIR derivatives regulation entails that financial operators need to assess their readiness to comply with the regulatory requirements. Among the issues that

they should consider, we highlight: identification of the TR where derivatives contracts should be registered; definition of the operational procedure for notifying derivative contracts registration requests; identification of the CCP that can clear the derivative contracts; definition of the relationship with the CCP, i.e., whether the counterpart can act as ‘clearing member’ or whether it needs to be a client of a clearing member; review, design and implement the operational procedures for fulfilling operational risk management requirements; assessment and provision of adequate guarantees (collateral) for non-cleared OTC derivative contracts.

Latest update on the status of the implementation of the new derivatives regulation was provided by the Financial Stability Board report “OTC Derivatives Market Reform: Eight Progress on Implementation”, issued on 7th November 2014. The report acknowledged that reform implementation was not completed yet, but progress was continuously made across jurisdictions as legislations were almost completely passed. Higher capital requirements for non-centrally cleared derivatives and trade reporting requirements were adopted in about three quarters of FSB member jurisdictions. Measures to promote trading on exchanges, however, seemed to be taking longer time than other reform initiatives.

4.4 Central Counterparts (CCPs) and their Role in the Regulation of Derivatives

Central Counterparts (CCPs) constitute an important component part of the emergent architecture of regulation of derivatives. These institutions provide a means for centralizing risk management (through processes of multilateral netting, collateralization, and loss mutualization) and data processing operations (through trade registration and reporting) (Steigerwald, 2013). CCPs bring some clarity to the network of financial derivatives contracts that would be otherwise rather ‘opaque’, in the sense that the multiplicity of connections (derivative contracts) between financial operators would be otherwise difficult to discern and understand. Without CCPs, no industry operator can have a complete overview of the relationships between risk protection buyers and seller. The presence of one (of more) CCPs, instead, “allows the numerous bilateral exposures of a market participant to be substituted for a single net exposure to a financially and operationally robust” counterpart (Reserve Bank of Australia, 2011: 12). A way to express this argument in a graphical form is conveyed by Figure 1, which shows how a complex network of bilateral clearing (without any CCP) can be simplified with the introduction of a CCP.

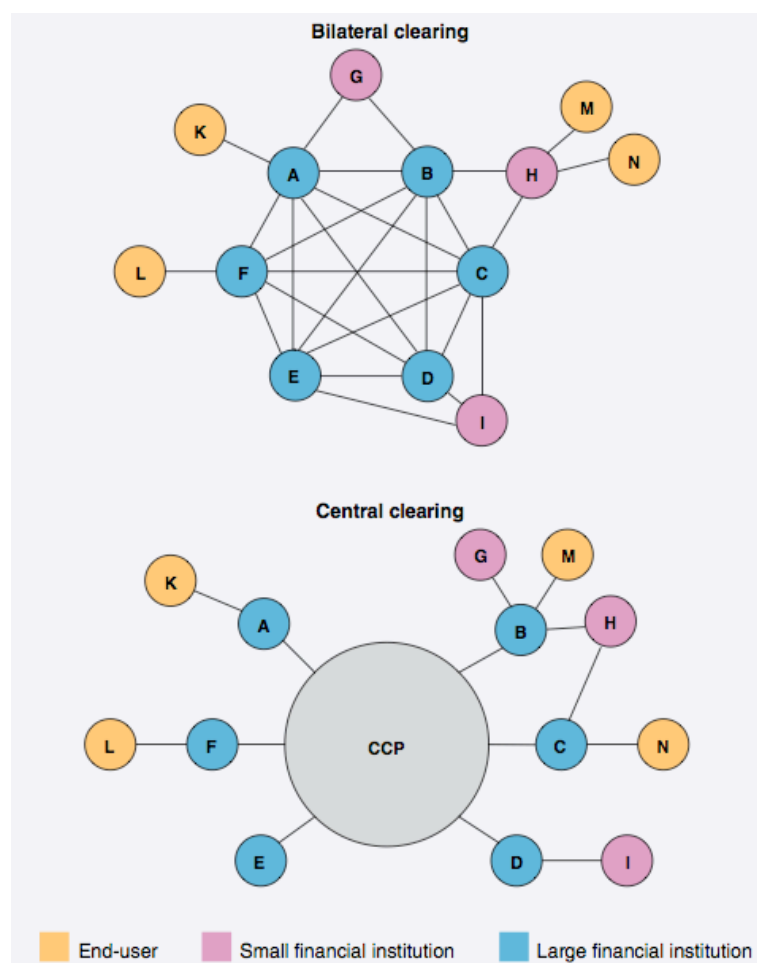


Figure 1. Financial derivatives contract networks without and with the presence of a CCP (source: Reserve Bank of Australia, 2011)

The role that CCPs can play in providing new sources of stability of the financial derivatives industry, however, has not been fully clarified so far. A number of additional studies and policy papers have identified ‘open issues’ that the present regulatory system, which includes a pivotal role for CCPs, may not be fully equipped to tackle in an efficient and effective way.

Kiff et al. (2009) provide an overview of some of the problems that the present derivatives regulatory system hosts. First, they argue that coordination between national regulators is needed in order to prevent conflicts that may arise when a CCP, which is based in a particular country jurisdiction, nets positions of derivatives that are written according to the terms provided in other country jurisdictions. Second, they held that more efforts could be exerted to improve the quality of information disclosed by financial institutions, including

financial reporting. Finally, they contemplated the possibility that CCPs may default and spread financial turmoil throughout the financial system, if regulatory and public authorities do not take adequate risk mitigation and risk management tools to protect the integrity of financial stability.

About the need for international regulatory coordination, Kiff et al. (2009) highlighted that, most likely, future regulatory scenario for derivatives is that there will be different CCPs located in different country jurisdictions, rather than any international CCPs that would be able to operate in more than one country. This would call for intensive cross-border coordination and supervision, especially in order to avoid regulatory arbitrage, help mitigating systemic risk, and avoiding hampering multiple-currency or cross-border transactions. In this context, the European Central Bank supported the creation of EU-based CCPs rather than having EU-based financial operators relying on CCPs based abroad (especially in the US). Also, a relevant initiative was the establishment, in 2009, of the OTC Derivatives Regulators' Forum, with the aim of adopting, promoting, and implementing consistent standards in setting oversight and supervisory expectations.

About the need for more quality of information disclosed by financial operators, Kiff et al. (2009) commented on the merits of the introduction of novel accounting standards (IFRS 7 and FAS 157, plus additional guidance documents) on the disclosure requirements for financial reporting. Part of the efforts to provide better quality of information have been directed to the application of fair value to financial products, although issues persist when markets are no longer functioning properly as it may be the case in a fire sale scenario, where liquidity of assets dries up and market prices diverge from fundamentals. Another part of the efforts have been directed to enhance the monitoring of trading activity in derivatives, although issues persist whenever trading in OTC derivative products is not communicated to TR because of exemptions and when communication is made to TR abroad but the derivative contract is relevant for a particular country's financial operator.

The scenario where a CCP defaults is another kind of issue in the regulation of derivatives that has attracted considerable amount of attention. Duffie et al. (2010) highlighted that, if a CCP is successful in clearing a large quantity of derivative trading, then the CCP becomes a systemically important financial institution. The default of the CCP, then, would expose a large number of financial operators to losses. This point is also discussed by Scott et al.

(2010), who argued that, by pooling risk, CCPs may exacerbate, rather than contain, systemic risk. Once created, therefore, the CCPs need to be carefully regulated because they pose issues akin to those of large financial institutions that are induced to take on too much risk in anticipation that, because of their ‘too big to fail’ status, public authorities would eventually rescue them from default.

In order to prevent the CCP to become a source of financial instability itself, Duffie et al. (2010) call for tight operational and financial controls, including especially risk management instruments, tools for quick recapitalization, and tools for reversing the position in derivatives with minimal impact on counterparts and markets. Regulators should ensure that CCPs are robust enough to sustain various sources of risk, including the defaults of multiple counterparts, sudden fire sales of financial assets and rapid reduction of market liquidity. Particular attention should be placed to anticipate issues that arise from ‘extreme but plausible’ loss scenarios (i.e., relatively rare events, also often characterized as ‘black swans’; Taleb, 2001), such as, for instance, large albeit rather unusual price movements.

Scott et al. (2010) argued that, in order to prevent acting as a source of financial instability, CCPs need to take measures to reduce their own risk, including membership and capital requirements and a backup clearing fund. CCPs, moreover, should be subjected to close regulatory scrutiny to ensure that measures are adequate and enforced. The authors also proposed that CCPs should apply margining requirements for out-of-the-money participants in a day-by-day basis, i.e., the CCP should assess the participants’ derivative contracts to market prices and, for those contracts that have declined in value, the CCP should ask the participants to provide additional collateral.

A related issue discussed by Scott et al. (2010) is about the number of CCPs. On the one hand, having a few CCPs (even just one, at the extreme) would result in more efficient netting and margining as the CCP would be in the position to possess information about a large number of derivative transactions. On the other hand, having a large number of CCPs, possibly organized by asset class as this relates to different risk management techniques, would prevent having a massive concentration of risk into ‘too big to fail’ financial institutions and would instill competition between CCPs, with potentially beneficial effects on prices of intermediation services and innovation. Scott et al. (2010) also considered possible, however, that market pressure would naturally lead the industrial structure of

CCPs, with the possibility that CCPs would eventually consolidate in a relatively small number.

A condition that may affect the industrial structure of CCPs, as well as the function of CCPs to contribute to systemic risk reduction, originated from the interoperability of CCPs, i.e., the possibility for CCPs to exchange information on derivative trading in a timely way and to conduct netting and margining requirements in a coordinated way. In principle, interoperability would result in both the benefit from having multiple CCPs (e.g., in terms of competitive pressures and innovation) and the one from having a coordinated approach to risk, especially in terms of netting positions of counterparts of different CCPs. In practice, however, issues arise with respect to the costs of administering interoperability and to the establishment of consistent regulatory standards across CCPs. Moreover, the establishment of linkages between CCPs would entail additional risks that relate to the operational, legal, liquidity and settlement implications of having two or more CCPs relate to each other through the same derivative trading. As a matter of fact, indeed, there has been relatively little empirical experience of CCP inter-linkages so far.

These and other issues call for a focused attention and research effort to place on better understanding whether CCPs can improve the stability of the financial system. In principle, CCPs clearly offer the possibility to ‘absorb’ or ‘cushion’ losses that originate from derivative contracts (e.g., swaps) because of the monitoring, supervision, and ‘guarantor’ role that they can play in the financial derivatives industry. Questions arise, however, as to whether CCPs are able to effectively perform this role when facing some of the actual conditions under which financial market operate, e.g., the high level of connectivity between financial institutions (that engage in multiple derivative contracts to hedge their positions and for speculative purposes), the presence of both systemic and institution-specific shocks, and the possibility that relatively large defaults impair the stability of the whole financial system. It is necessary, therefore, to explore the effects of CCPs under different conditions of the financial system, which also include how sources of financial instability can or cannot be effectively countered by this novel regulatory instrument.

Chapter 5

The Simulation Method: Implementing Agent-Based Models

5.1 The Simulation Method: An Overview

The aim of this study is to address the general issue of how derivatives markets can be effectively regulated. By effectively regulated we mean that derivatives markets should exhibit the property of a satisfactory resilience towards sources of systemic crises that can undermine financial stability. By satisfactory resilience we mean that derivatives markets should be able to absorb relatively high losses related to credit or other events (depending on the kind of underlying assets) without compromising the stability of the financial system. The term ‘satisfactory’ cautiously relates to the assumption that complete solidity of the financial system with respect to any source of systemic risk may be unattainable, if not at relatively high costs and/or constraints imposed on financial activity (e.g., the prohibition to trade in derivatives). As such, any assessment of the amount of confidence placed on the resilience of the financial system, and therefore of the adequacy of the regulatory system, is related to the subjectivity of the policy-makers or the regulators. The contribution of this study, in this respect, is the one to assist key decision-makers to formulate a better-informed judgment, based on theoretical and empirical work.

Within the present temporal context, the question as to how derivatives market can be effectively regulated necessarily relates to the experience drawn from the recent Great Financial Crisis and the policy response to it. Accordingly, the question calls into play the regulatory tools that have been devised in the last a few years: How effective are the measures taken for regulating derivatives markets as formulated in the concerted policy initiatives undertaken within G20 (and other) countries, i.e., those included in the Dodd-Frank Act in the US and in the EMIR, CRR, and MiFID II in the EU? To what extent do these measures entail that the financial system is satisfactorily resilient to sources of systemic risk in the future? Answers to these questions are important in order to anticipate whether the financial system is able to contain the insurgence and spreading of financial crises and, if sources of weaknesses are still present in the regulation of financial activity, where they are located and what measures can be taken to counteract them.

Taking into account the general features of the present regulatory system of derivatives markets, some of the main issues that relate to the effectiveness of derivatives regulation are:

1) Does the requirement to report derivatives trading to TR improve financial stability?

The immediate effect of reporting derivatives trading to TR is the one to reduce asymmetric information between the regulatory on the one hand, and the conduct of financial operators on the other one. By collecting information about derivatives trading in a centralized repository, the regulator can monitor concentration of risk in any financial operator and, if appropriate, take appropriate measures. In order to assess whether the reporting of derivatives trading to TR improves financial stability, we need to consider whether (a) trading information enables a regulatory authority to identify concentration of risks that may be detrimental to financial stability, (b) whether the regulatory author possess the tools for correcting the conduct of financial operators that results in such concentration of risks, and (c) whether, in consideration of the possible actions taken by the regulatory authority, financial operators may conveniently adjust their conduct.

2) Does the requirement to trade through CCPs improve financial stability? The immediate effect of trading through CCPs is the one to interpose a CCP in between the counterparts of derivatives trading. The CCP is expected to sustain the losses that may arise if any counterpart defaults, i.e., it is not able to fulfill the obligations that arise from the derivative contracts, either at all or at cost of losses that arise when trying to keep liquidity positions. In order to assess whether CCPs help attaining greater financial stability, we need to consider under which conditions CCPs are able to absorb losses: Could the default of a single, relatively large, financial operator on derivative contracts bring down the ‘cushion’ provided by the CCP? Or could the CCP be severely hit by the concurrent default of several, relatively small, financial operators on derivative contracts rather than of single, relatively large, one? Could the default of a single, relatively large, financial operator impact on the CCP through a ‘side route’, if, for instance, losses are propagated from the large financial operators to smaller ones and eventually to the CCP? How should we expect financial operators to adjust their conduct because of the requirement to trade through CCPs?

3) *Do non-cleared derivatives transactions pose any threat to financial stability?* The immediate effect of having some derivative trading not cleared through CCPs is the one that counterparts of the non-cleared derivatives trading carry the risk without the ‘cushion’ provided by CCPs. In terms of financial stability, this entails that defaults on the derivatives contract would impact the counterpart and, potentially, losses may propagate to other financial operators as well. In order to assess whether the presence of non-cleared derivatives transactions poses any threat to financial stability, we need to consider whether, in a context where other derivatives contracts are cleared through CCPs, losses that may arise from the non-cleared transactions may be contained by the presence of other measures taken to regulate cleared derivatives, i.e., whether the CCPs and the other regulatory tools may provide mechanisms of containment of the losses to the counterparts, or to a limited number of other financial operators only, rather than permitting the contagion to other parts of the financial system.

4) *How much collateral is needed to safeguard financial stability?* The immediate effect of collateral requirements is the one to increase the capacity to absorb losses in counterparts of derivatives transactions. As such, collaterals should be keyed to the amount and likelihood of losses related to particular derivatives contracts. In order to assess whether collateral requirement helps attaining greater financial stability, we need to consider whether the collateral measures take into account the additional risk that particular derivatives trading pose to the financial system. That is to say, the effects of any derivative contract are not circumscribed to the counterparts only, if the default of any counterpart entails the possibility of loss repercussions to other parts of the financial system. In such conditions, should collateral requirements include a charge related to the negative externality that the additional derivatives contract pose to the whole risk-shifting structure provided by the aggregate amount of derivatives transactions? How much collateral should financial operators provide in order to contribute to the resilience of CCPs in face of the additional systemic risk that their derivatives transactions pose?

Answers to these questions seem important in order to better equip the system of derivatives regulation to cope with possible future sources of systemic risk. While the present regulatory system includes various measures that are expected to limit the excesses of derivatives trading experienced in the pre-Great Financial Crisis period, there are good reasons to expect that derivatives will be part of the strategy of financial institutions and

business alike in the future. Derivatives play a fundamental role in the de-coupling of risk and return profiles attached to real and financial investments: they enable, through various forms of financial engineering and securitization, the shift of risk to financial operators who are most willing to take on additional risks for a commensurable market price and the design of less risky assets for investors who are willing to accept relatively lower returns.

This work focuses, in particular, on the research question whether the requirement to trade through CCPs improve financial stability. In principle, the introduction of one or more CCPs can provide a source of resistance to shocks to the financial system, because the CCP would ‘absorb’ or ‘cushion’ losses that hit financial institutions – apart from enabling better monitoring and surveillance of the financial system. The CCPs, however, would operate within a complex environment, where the high level of interconnectivity between financial institutions would result in the possibility that losses propagate across the financial system and result in the destabilization of large and/or numerous financial operators. The complexity of the networked structure of the financial system – especially, the part that related to the financial derivatives industry – makes it analytically difficult to derive solutions about the impact of CCPs. An alternative approach, that is followed here, is to adopt simulation techniques – namely, agent-based models – for drawing computational inferences about the effects of the presence of CCP as tools for regulating the financial derivatives industry.

5.2 General Features of Agent-Based Models

Simulation is often regarded as a methodological ‘third way’ to conduct scientific enquiry but the canonical ‘inductive’ and ‘deductive’ approaches (Axelrod and Tesfatsion, 2006; Wallace, 2009). Simulations do not consist, as ‘inductive’ kind of research does, in the hypothesis-generation or hypothesis-testing activities based on the analysis of empirical evidence. Also, simulations do not consist, as ‘deductive’ kind of research does, in the formulation of logically-derived hypotheses or conclusions from axiomatic premises. Consequently, simulations also differ from any kind of mixed ‘deductive-inductive’ kind of research that provides the analysis of empirical evidence for testing theoretically-derived hypotheses. Rather, simulations have been considered a method for ‘generative’ research (Epstein, 1999) that primarily aims to formulate explanations of the emergence of features of behavior of an entity at an aggregated level on the basis of features of the conduct of entities, and of their interaction, at a disaggregated level. Simulations, for instance, seek to

explain the emergence of market price patterns of a commodity (i.e., a market-level feature) on the basis of the conduct of, and of the interactions between, buyers and sellers (i.e., a market participant-level feature).

Simulations are generally built around some key assumptions of the entities at both the aggregated and disaggregated levels (Young, 2006; Epstein, 2006):

1) Heterogeneity: simulations typically assume that, at the disaggregated level, the entity is made of heterogeneous component parts. For example, a simulation of the emergence of market price patterns of a commodity builds on the assumption that market participants are not alike, i.e., that each buyer and seller is unique in some respect, possibly because of their endowments, preferences, expectations, etc. This assumption characterizes simulations as typically different from most of theoretically-driven deductive research, that generally builds on the simplifying assumptions of homogeneity of representative agents.

2) Local interactions: simulations typically assume that, at the disaggregated level, the entity is made of heterogeneous component parts that interact with a limited number of other parts. For example, buyers and sellers may interact, in the form of exchanging information about bid and ask prices, with a limited number of other market participants, with whom they are connected through particular channels, e.g., network ties or other kinds of n-dimensional lattice. Also this assumption characterized simulations as typically different from most of theoretically-driven deductive research, that generally builds on the simplifying assumptions that the networked pattern of interaction between agents is not analytically relevant to explain aggregated outcomes. Rather, simulations are generally very sensitive to the way in which agents are connected, and features of the topology of networked patterns typically play an important role in the process dynamics and outcome of the system at the aggregated level.

3) Bounded rationality: simulations typically assume that, at the disaggregated level, the entity is made of heterogeneous component parts that interact with a limited number of other parts according to decision criteria characterized by a limited capacity to process a limited amount of information. Simulations, however, differ in the extent to which they assume agents possess fixed or changeable computational capabilities, i.e., whether they follow pre-determined and immutable decision rules or they are provided the possibility to

adjust (or to evolve) their computational capabilities especially on the basis of performance of past decisions and of other agents' conduct (e.g., imitation of others' behavior) (Secchi, 2010). When agents are provided the possibility to adjust their computational capabilities, then simulations may incorporate procedures (e.g., algorithms) that originate from the field of artificial intelligence. By making decision rules dependent on adjustments based on other agents' conduct, moreover, simulations are typically able to reproduce certain properties of social phenomena, such as, for instance, so-called 'herding' behavior when groups of agents exhibit certain consistency of behavior at the group aggregated level.

Generally, simulations do not pose any particular requirement or presupposed constraint about the conduct of the entity at the aggregated level: rather, they consist of computational experiments that allow the emergence of behavioral patterns at the aggregated level - possibly, of regularities - on the basis of the assumptions formulated at the disaggregated level only. In other terms, simulations are intended to produce explanations in the form of reconstructions, through computational systems, of the properties of entities at the aggregated level in a 'bottom-up' fashion (De Grauwe, 2010). As an epistemological program, therefore, simulations exhibit both reductionist and holistic components: on the one hand, explanations of phenomena at a certain level of analysis build on the aggregated effect of behavior exhibited at a lower level of analysis (along the generative social science motto that 'if you do not grow it, you don't explain its emergence'; Epstein, 1999); on the other hand, the conduct of entities at the disaggregated level of analysis does not amount, by itself, to an explanation of the phenomena at the level of analysis of interest, if not taking into account the effect of the interactions between behavior at the disaggregated level (Epstein and Axtell, 1996; Axelrod, 1997).

Simulations exhibit many properties of how it is generally understood that social systems work (Batten, 2000). Simulations include heterogeneous agents, that make choices in discrete - rather than continuous - steps. Simulations include the possibility that the interaction between agents and their choices are affected by various kinds of frictions, e.g., limited information or information processing capabilities. Simulations tend to exhibit path-dependency, in the sense that the dynamics of the system is affected by the past trajectory of the same system. Simulations may exhibit relative stability (steady states) or chaotic behavior, or periods of relative stability may be interrupted by sudden alterations of the apparently stable conditions. Simulations may also result in the evolution of an apparently

chaotic system into one that exhibits some form of self-organization, in ways that are not necessarily dictated by any central coordination agency but rather emerge, in an unintended way, from the decentralized interaction between agents. Simulations also allow to explore how minimal perturbations of the system may escalate into system-scale effects, especially in terms of disturbances of the apparent organization, or in self-regulation properties of the system as a whole.

The view that societies and economies display the properties of self-organizing systems is intellectually rooted in the tradition of Adam Smith, Frederick Hayek, and Joseph Schumpeter, and it is contrasted with other approaches, such as neoclassical economics, that build on different assumptions. Theoretical approaches informed by neoclassical thought, such as in the Walrasian equilibrium, typically assume that agents are homogeneous, that they typically make choices according to canons of ‘hyper-rationality’, and that they have no cognitive limitations (Pyka and Fagiolo, 2005; Tesfatsion, 2006). The intellectual approach followed within simulation studies, instead, allows the idea of the emergence of regularities in the social and economic behavior at the aggregated level on the basis of a restricted number of assumption on the conduct of agents at the disaggregated (Schelling, 1978; Axelrod, 1984; Arthur, 1994). As highlighted by Tesfatsion (2002), agent-based simulations also build on the concept of a two-way feedback between micro-structure and macro-structure: on the one hand, the interaction between agents at the disaggregated level results in the emergence of properties at the aggregated level; on the other one, properties at the aggregated level affect disaggregated interactions as agents take into account or are constrained by the state of the system.

One main implication of simulation-based method to research of social and economic system is the acknowledgement that, most of the times, such systems are in an inherent out-of-equilibrium condition (Arthur, 2006; Epstein, 2006). Neoclassical economics is intellectually oriented to identify the conditions that lead to equilibrium of market forces, for example. In contrast, the simulation-based method results in explanations of system dynamics and outcomes that rarely provide the possibility to reach steady state conditions as neoclassical economic (and other) approaches typically do (e.g., duopoly models, Nash equilibrium, etc.). More often, explanations result in the identification of the conditions for the emerge of patterns that may never ‘settle’ to assume relatively stable properties. With respect to other intellectual approach keyed to the specification of equilibrium conditions,

simulation-based methods are rather concerned with explain *whether* and *how* equilibrium conditions are reached, or *why* they are not reached at all along the process dynamics of a system.

Proponents of the simulation-based method highlight that this method can result in significant advancement within social sciences, and in the fields of economics and finance in particular (Farmer and Foley, 2009). Colander et al. (2009) argued that, indeed, evidence provided by the inability of the economic profession to forecast the coming of the Great Financial Crisis suggests that alternative approaches - that especially do not take for granted the presumed self-regulatory capacity of markets to reach equilibrium conditions - should be granted more consideration. Simulation-based methods - with their attention paid to the emergence of complex dynamics that originate from the disaggregated interaction of heterogeneous agents - can provide the intellectual framework, methodological guidelines, and operational tools for addressing questions about what happens to social and economic systems when they change over time and when the possibility of reaching a stationary equilibrium is not given (indeed, when the same properties of the disaggregated mode of interaction do not necessarily provide the possibility that any equilibrium can be reached).

During the last about two decades, agent-based models have emerged as a relatively popular simulation technique in social science (Axelrod, 2006). Agent-based models (ABMs) precisely consist of simulation techniques that enable to generate patterns at an aggregated level of analysis on the basis of computations of interactions that take place between a number of heterogeneous agents at the disaggregated level. Within the field of economics, ABM have been largely applied in the area of so-called agent-based computational economics (ACE). Tesfatsion (2000) defined ACE as “the computational study of economies modeled as evolving systems of autonomous interacting agents”. The central concern of ACE is to understand why certain global regularities have been observed to evolve and persist in decentralized market economies even if there is no top-down planning and control. The aim is to demonstrate how system-level regularities arise from the bottom-up, through the repeated interaction of autonomous agents acting in their own perceived self-interest.

ABM are typically implemented through computer simulations that generate simulated data about properties of the process dynamics and outcome of a system under consideration

(Axelrod and Tesfatsion, 2006). There are different ways to construct ABM simulations depending on the sophistication of the assumptions regarding the conduct of agents at the disaggregated level. Design choices of the simulation include, in particular:

1) What are the criteria that inform the choices made by agents: agents may make decisions on the basis of pre-determined information processing rules (e.g., self-interest seeking agents), or on rules that are progressively adjusted in relation to new information (e.g., performance feedback), or on rules that are progressively adjusted in relation to the apparent behavior of other agents (e.g., internalized social norms);

2) How much information processing capacity agents have: agents may be able to process a very limited amount of information (e.g., information about properties of the present state of the system, or of a part only of the system), or they may be able to acquire, store and process a larger amount of information (e.g., information about properties of both the present and the past state of the system, or of a part only of the system), or they may be able to infer additional information on their own (e.g., information about expected future properties of the state of the system, or of a part only of the system);

3) Whether agents are able to adjust their information processing capacity over time, especially along a process of learning (Brenner, 2006) that results in the improvement of the selection and use of information for making choices: agents may not be able to learn anything new, and therefore their choice criteria and information basis tend to be relatively stable over time, or they may be able to learn, drawing on performance feedback, observation of other agents' conduct, or other mechanisms for modifying the kind and amount of information that they select and the procedures (algorithms) they use for taking choices.

4) How many agents any agent is able to interact with, and how they are selected: agents may be able to interact with all other agents at any moment in time, or they may be able to interact with a limited number of other agents, who are selected depending on the topology of the interaction structure (e.g., on the basis of physical proximity in an n-dimensional lattice or on the basis of structured network ties).

5) *How fast are adjustments to the newly acquired information*: if agents react too slowly to information (e.g., information about changed conditions of the environment or about the conduct of other agents or about any dimension of desired performance) then the dynamics of the system may result in dissatisfactory outcomes that agents are not able to correct any more; if, on the other hand, agents are too fast to react to new information (i.e., they ‘over-react’) then the adjustment of their conduct can throw additional sources of instability into the system.

ABMs enable the researcher to investigate various kind of issues, that include the identification of conditions that increase the likelihood of cooperative solutions, that result in the over-exploitation of common-pool resources, that affect consequences of decisions taken in scenarios with high uncertainty, and that affect consequences of decisions because of the features of the topology of interactions among actors (Janssen and Ostrom, 2006). While these issues are not alien to the general concern of social science disciplines, what distinguishes ABMs is the possibility to investigate them under what are generally considered more realistic assumptions than most theoretical approaches, i.e., that agents face structural uncertainty, that they are heterogeneous, and that they interact in modes that are determined by idiosyncratic circumstances. ABMs, in this respect, help showing that, if these more realistic assumption are included, then we can explain a wider range of features of process dynamics and outcome of social and economic systems, and we can design better interventions to prevent unwelcome system-level behavior to happen.

Following ABMs offers two main advantages (Pyka and Fagiolo, 2005). First, ABMs enable the researcher to identify sources and conditions that determine certain properties of the process dynamics and outcome of systems at aggregated level. In this way, the researcher can potentially identify whether any particular agent plays a pivotal role in the emergence of properties at the aggregated level, or whether certain conditions or features of the interaction drive the evolution of the system. In principle, ABMs also allow to identify the circumstances associated with dramatic adjustments in the behavior of the system at the aggregated level, such as, for instance, the disruption of order and the emergence of chaos. Second, ABMs also enable the researcher to explore alternative conditions, including possible interventions, to the system, with the possibility to anticipate ‘in vitro’ their effects on the process dynamics and outcome of the system. In this respect, ABMs play the role of

‘virtual laboratories’ where alternative institutional and organizational arrangements can be explored.

Simulation-based methods, and ABMs in particular, also have some limitations (Teshfatsion, 2005). The main source of criticism on simulation research is that results of the simulations may have little relevance if they do not fit empirical facts. In this respect, an issue arises about how simulation models can be ‘calibrated’ so that the results of the simulation (i.e., data about properties of the process dynamics and outcome of the simulated system) match those of empirical phenomena. Some authors argue that simulation-based research should not be concerned with empirical validation, as the insights that are provided when understanding how the aggregated behavior of decentralized agents results in system-level properties are primarily of qualitative sort (Pyka and Fagiolo, 2005). As a matter of fact, ABMs are used in a rather flexible way, sometimes with the intended effect of replicating ‘in vitro’ some properties of empirical phenomena, sometimes with the aim of exploring the behavior of a system under different configurations of the parameters of the model.

5.3 Applications of ABMs in Economics and Finance

Simulation, especially in the form of agent-based models, have been used in a number of areas within social science research. Among the various instances of application of ABMs, the Santa Fe Artificial Stock Market deserved particular attention. Created by the Santa Fe Institute in 1989 (LeBaron, 2002), the model has been subjected to various development with the intention to better understand the dynamics of stock markets under different conditions. Works that resulted from the Santa Fe simulation include, for instance, Arthur et al.’s (1996) work on asset pricing, that included the role of expectations of other agents’ behavior in the formulation of actors’ conduct, including a role for market psychology, positive feedbacks, and bandwagoning effects. When these features are incorporated into the model, the simulation of stock markets exhibits some properties that are typical of empirical evidence financial market time series, such as bubbles, crashes, and erratic behavior of prices rather than the identification of market clearing prices along the lines of rational economic agents. The results of the simulation, in particular, highlight the role played by the pace of adaptation of agents’ conduct rules: slow adaptation to new information results in market convergence in a rational expectations fashion, while faster adaptation results in more chaotic price patterns.

The work of the Santa Fe Institute on ABMs has been carried forward in various other works, including LeBaron et al.'s (1999) study of the introduction of artificial intelligence properties of the agents. The simulation resulted in the replication of various features of market behavior, including the emergence of condition where the market prices 'stabilizes' around equilibria as they would be defined by agents who behave according to canons of rational expectations. The results that the simulation delivered were eminently qualitative, i.e., the parameters and the results of the simulation were not calibrated to fit any empirical evidence. Yet, future developments of the model include adjusting parameters to fit actual financial time series, apart from introducing risk aversion preferences, coordinating social behavior between agents, and implementing more advanced artificial intelligence systems (LeBaron, 2002).

Along the lines of the Santa Fe model, several other works have also used ABMs to the study of financial markets (Teshfatsion, 2002), especially because of the apparent promise of ABMs to help solving some among the main issues that analytic approaches have not been fully able to tackle yet, e.g., fat-tailed asset return distributions, high trading volumes, persistence and clustering in asset return volatility, and cross correlations between asset returns, trading volumes and volatility (LeBaron, 2006). Various research directions have been pursued, including the introduction of alternative assumption about agents' decision making rules, different way of using information and storing past data, and different learning mechanisms. Lux and Marchesi (2000), for instance, used an agent-based model for examining the volatility of financial markets. The work of Soramaki and Galbiati (2008) employed an ABM for exploring banks' allocation of liquidity to manage the settlement process, especially in relation to the issues that arise from an exogenous and random stream of payment orders. The one of Thurner (2011) employed an ABM for understand the leverage cycle and financial market crashes on national scale and their consequences. Also Bookstaber (2012) used an ABM to analyze threats to financial stability. Using the ABM simulator 'Eurace', which was built with the intention to provide a simulator of the whole European economy, Cincotti et al. (2012) examined the role of borrowing and debt load and their impact on the real economy, in ways that include the stimulation of economic activity by credit expansion and the depressive effects of credit crunch.

Another important area of application of ABM models is the one of understanding the origins of financial crises and the policies that could be employed to prevent or contain

them. Buchanan (2009), for example, discussed how ABMs help exploring how regulation can deal with out-of-equilibrium situations. He noticed that ABMs can assist regulators to anticipate the effects of regulatory measures by simulating the likely consequences of the adjustments of behavior of the regulated to changed regulatory conditions. In addition, Buchanan (2009) highlighted that ABMs can also incorporate the anticipation of regulatory measures from the side of agents, as well as the strategies that agents can follow for avoiding the unwelcome aspects of the regulatory burden. Simulation approaches, therefore, can provide a way to model and understand the kind of ‘arms race’ that the regulators and the regulated undertake when adjusting their policies, in a co-evolutionary fashion, to the conduct of other players.

Markose (2012), in particular, explored the use of ABMs (as well as of network modeling) for understanding the role of CDS in the origin and proportion of the Great Financial Crisis. He highlighted that the use of CDS introduce so-called ‘reflexivity’ properties into the financial system, in the sense that risk protection sellers suffer from an increase of CDS spread when the value of the underlying asset that they protect deteriorates. The consequence of the decrease of value of the underlying asset, in fact, can be the default of both the risk protection seller and the holder of the devalued asset, with the resulting effect that, rather than making the financial system more resilient, the use of CDS may result in exacerbating the consequences of a drop of price of underlying assets. According to Markose (2012), CDS markets typically exhibit more fragility than it is usually assumed, also because financial operators are willing to take on much more risk than the risk protection sellers are actually capable to support. Pivotal risk protection sellers (or ‘super-spreaders’ as they are called by Haldane, 2009) should be made more robust, especially by increasing the requirement to hold buffers against potential losses.

In another work, Markose et al. (2012) developed an ABM that included attention to bank balance sheet and off-balance sheet activity in response to changes in regulatory policy and under competitive co-evolutionary pressures to grow market share. Their model especially focused on the role of CDS in the origin of the Great Financial Crisis, and was intended to show how the dense interconnection in the network of financial relationships played an important role as a source of systemic risk. They concluded that structural weakness in modern risk sharing institutions arises from too much concentration of market share among a few broker-dealers.

5.4 An ABM of the Derivatives Market

The operationalization of the simulation method entails the making of various design choices in the building of an ABM. Design choices include the definition of the features of the system to simulate, especially in terms of the entities at the disaggregated level, the topological boundaries and properties of the system, the modality of interaction between agents, and the computational properties upon which the choices of the agents rest (Gilbert and Terna, 1999). These choices relate, in particular, to the variety of types of agents, to their properties, and to the initial distribution of their properties; to the kind of connectivity between agents and the possibility for agents to interact with others; to the type of resources or information that agents can exchange with each other; and to the type of information that the agents can perceive from the environment, how much information they can store in memory, how they make use of the information for computing which kind of choices, and whether and how they can adjust how computations for choice are made.

At the core of the conduct of any agent is the so-called ‘production system’ (Gilbert and Terna, 1999). The production system is composed of a set of rules, a working memory and a rule interpreter. Rules are formed of two parts, namely a condition that specifies when the rule is executed and an action part that specifies what is the consequence of the activation of the rule (i.e., an ‘if... then...’ structure). Some rules, however, may also modify other rules, as if agents possess computational capabilities to repair some rules depending on specified conditions. In this way, it is possible to provide agents an elementary cognitive capacity. Alternatively, agents may be provided with some algorithms that assist in the refinement of rules in an adaptive fashion, e.g., neural networks or genetic algorithms that result in the progressive adjustment of agents’ computational structures depending on various kinds of performance feedback mechanisms (Tsfatsion, 2002). The working memory assists the computation by storing data that can be recalled for either the present or for future computations. Finally, the rule interpreter provides the identification of which rule should be applied given the particular circumstances where an agent operates.

The connectivity between agents can be modeled in different ways. Some ABMs place agents in a n-dimensional lattice, where agents may occupy either fixed or variable positions. Within the n-dimensional lattice, agents are typically allowed to interact with a limited number of other proximate agents, e.g., in a typical flat matrix structure, any agent

that occupies one 'cell' of the matrix can interact with the nine cells in the immediate surroundings in the matrix. Other AMBs, instead, provide agents with the possibility to interact with any other (albeit, typically, with a limited number of other agents) through the establishment of network connections. The choice of the connectivity model depends on the features of the social and economic system to reproduce, where in some cases it is relevant to constraint the interactions on the basis of physical proximity while in other instances distance is not relevant to limit interaction.

The interaction between agents can also be modeled in different ways. Typically agents exchange information with each other, possibly about their status or properties or about features of the environment. Agents, however, can also exchange various kinds of resources, such as, for instance, financial or real assets, commodities, and money. Depending on the kind of interaction, agents should be equipped with a registry of their status or properties, such as, for instance, the record of assets or other resources that they control. The interaction, moreover, is governed by rules, which should specify under which condition the exchange of information or resources takes place. For instance, rules can specify under which conditions one agent transfers some information or resources to another one, and whether the other agents should reciprocate. The rule interpreter, in this instance, should specify which features of the status or properties of the agents, and possibly of the environment, determine the activation of the exchange rule.

As agents interact through their connections over time, they may adjust their production systems along a learning process. There are several kinds of learning mechanisms that agents can follow (Brenner, 2006). In Bayesian learning, agents adjust their production system on the basis of evidence provided by performance feedback that impact upon the pre-existing (hypothesized) rules that the agent followed. In genetic programming, agents possess the capacity to select, reproduce, cross-over and mutate parts of the rules depending on feedback about the performance of existing rules. In neural networks, agents possess computational cognitive structures arranged in a networked connectionist fashion and the capacity to adjust network features (i.e., weights on the interconnections between artificial neurons) depending on feedback about the performance of the present network. As agents adjust their production systems, they develop adaptive responses to changing environmental conditions in ways that typically it is not possible to figure out in advance on the basis of a pre-specified set of equations (Markose et al., 2012). In other words,

openness to learning paths results in emergent properties of the complex adaptive system (CAS) at the aggregated level that are not analytically tractable with econometric tools and time series data.

These design features result in a greater or lesser extent to which the structure of interactions between agents changes over time. If agents behave according to static rules and along stable connections, then their interaction may result in relatively ordered patterns or stable outcomes. If, instead, agents behave according to changeable rules and along connections that are redefined depending on past performance feedback and contingent conditions, then their interaction may exhibit traits of chaotic behavior (Pyka and Fagiolo, 2005). The emergence of chaos and the possibility to investigate under which conditions chaos emerges are, indeed, among the peculiar features of ABMs.

ABMs can be implemented through different software instruments. At the simplest form, ABMs can be implemented through low-level programming languages, such as plan C or DOS. Alternatively, it is possible to use computational tools (such as Excel or R), high-level object-oriented programming languages (such as C++), or ABM software (such as Swarm or Netlogo). The selection of the software instrument depends on the complexity of the model, as well as on the desired output and reporting features of the simulation exercise. In principle, it may be possible that the agent interaction can be modeled in analytical form (i.e., through systems of equations) and that the resulting interaction can be analytically solved, but generally the complexity of the model - understood in terms of heterogeneity of agents, number and kind of connections, and changeability of the interaction rules - entails that the model eludes analytical treatment. In addition, of course, the computational approach also allows to observe the very trajectory of the behavior of the system at the aggregated level, that is typically one of the aims of the simulation-based method.

These considerations about the design of ABMs are relevant for the purpose of the present work. Policy measures taken by policy-makers for regulating the derivatives market entail some fundamental changes in the connectivity structure of the financial system and on the inducement and constraints placed on financial operators (Zigrand, 2010). Issues arise, then, about how new structural and procedural rules are going to impact the conduct of individual financial operators and what kind of repercussions they may have on the

behavior of the financial system - or, at least, in the part of the financial system that relates to the trading of derivatives - as a whole. The establishment of CCPs, for example, brings about the reconfiguration of the network of relationships between financial operators: the consequences of the centralization of derivatives trading through CCPs are not fully evident, e.g., whether CCPs provide a buffer from market shocks or whether they could, by themselves, introduce additional source of instability under particular, albeit extremely rare, market circumstances. The simulation approach, therefore, can help providing answers to questions about the resilience and effectiveness of CCPs.

Chapter 6

The Design of a Model of Financial Derivatives Industry

6.1 The Design of the Model

The design of the model of financial derivatives industry that is developed for the present study consists of a few component parts, namely: (a) the definition of the agents that populate the model, (b) the definition of the routines that drive the behavior of the agents, and (c) the definition of input-output interface that enables the researcher to run alternative simulations (depending on the parameters set for the model) and to see the results of the simulation (especially at the aggregated level). The design of the model includes two variant – Model A and Model B – in order to enable the investigation of alternative effects of regulating the derivatives industry with or without central counterparts.

Like any model, also the present one is designed on the basis of relatively simplifying assumptions. First, agents are characterized by a limited number of features, which especially include two stock variables and two flow variables. The two stock variables relate to assets (credits in the case of banks and investment assets in the case of credit protection sellers and central counterparts) and equity (reserves), while the two flow variables relate to losses that are passed to other financial institutions and losses that are received from other financial institutions on the basis of credit protection contracts (i.e., swaps). Second, the behavior of the agents is driven by algorithmic rules, which include absorbing losses on credits or on assets if agents cannot pass losses to other financial institutions on the basis of credit protection contracts or passing losses to other financial institutions if there are credit protection contracts and the counterparts can fulfill their obligations. Third, bank agents are affected by random credit default events that depend on both general exposure to default risk (i.e., all bank agents can be hit by default of part of their clients) and idiosyncratic exposure to default risk (i.e., every bank can be hit by default of part of their clients in relation to bank-specific risk conditions).

The model is also characterized by some features that are intended to replicate the networked structure of the financial derivatives industry. In Model A, each bank agent is connected to one or more credit protection sellers and, if a bank is left without any connection to any credit protection seller (e.g., if a credit protection seller goes bankrupt)

then the bank seeks for at least one new credit protection contract with any financial institution. Credit protection sellers, moreover, are connected to one or more other credit protection sellers and, if a credit protection seller is left without any connection to other credit protection sellers then it seeks for at least one new credit protection contract with any financial institution. In Model B, every credit protection seller is not allowed to connect to another credit protection seller directly; rather, all credit protection sellers are connected to a central counterpart, which serves as an intermediary to the linkages between any two credit protection sellers. The extent to which agents (banks, credit protection sellers and central counterparts) are connected to others is controlled by the degree of connectivity of the network – parameters that can be set by the researchers.

The researcher can manipulate the setting of the models in various respects. Inputs to the model include the number of banks, of credit protection sellers, and (in Model B) of central counterparts; the degree of connectivity of the agents with other agents; the exposure of banks to general credit default risk conditions and to random credit default events that are bank-specific; and the magnitude of credit losses when banks are hit by default events. The researcher can also observe the behavior of the model by looking at aggregated indicators, such as total number of agents of each category, total number of linkages between agents, total credit and other assets, and total reserves. The trajectory of these aggregated indicators provides the evidence that is relevant to draw inferences on the role of model conditions (inputs to the models and, when comparing Model A with model B, the presence or absence of central counterparts).

The model is implemented in the Netlogo language. Netlogo (<https://ccl.northwestern.edu/netlogo/>) is a programming environment that has been widely used for implementing agent-based models. The first version of Netlogo, developed by Dr Uri Wilensky, director of the Center for Connected Learning & Computer-based Modeling of Northwestern University (USA), appeared in 1999. It is a free open-source software under a GPL licence.

Next sections of this chapter illustrate the construction of the model in detail. The full code of the model is reported in the Appendix of the present work. Next chapter, instead, will report and discuss the results of the model simulation.

6.2 The Setup of the Model

The model contains, in both Model A and Model B variants, two types of agents, namely banks and credit protection sellers. Model B also contains a third type of agent, namely the

central counterparts. The construction of the model takes place in Netlogo by generating these types of agents first. This is done in Model A with the instructions:

```
breed [banks bank]
```

```
breed [cpss cps]
```

and in Model B also with the instruction:

```
breed [ccps ccp]
```

Next step is to create the networks between actors. Model A includes two types of networks: one that connects banks with credit protection sellers (i.e., swap contracts between banks and credit protection sellers) and another that connects credit protection sellers with each other (i.e., swap contracts between credit protection sellers, provided that a credit protection seller that negotiates a swap with a bank client can enter other swap contracts with other credit protection sellers to have credit protection on the same swaps with banks). These networks are implemented with the following code:

```
undirected-link-breed [bank_cpss bank_cps]
```

```
undirected-link-breed [cps_cpss cps_cps]
```

Model B, instead, the second network relates to the connections that credit protection sellers have with central counterparts, provided that – in Model B scenario – credit protection sellers do not enter credit protection contract with each other but through the intermediary role played by central counterparts. The network between credit protection sellers and central counterparts is implemented with the following code:

```
undirected-link-breed [cps_ccps cps_ccp]
```

Next step is the initialization of the variables to define what are the features that characterize any type of agent. The bank agents are characterized by five variables. One variable relates to the amount of credits that the bank has (i.e., loans with clients), and that can be exposed to the risk of credit default. Another variable relates to the amount of reserves (as part of equity) that the bank has, which can be eroded by losses on credits.

Another variable relates to the probability that the bank suffers from default on its credits (this probability is bank-specific, while the model also includes a general probability that a credit default hits any bank). Another variable relates to the amount of loss on credits that the bank may suffer at any period of time (and that the bank may pass to credit protection sellers, if the bank has any connections with them, or carry in the income loss of the period, if the bank has no connections with any credit protection seller or if the connected credit protection sellers have no means to refund the bank for the loss). Finally, another variable relates to the amount of loss on credits that the bank can pass to credit protection sellers. This is implemented with the following code:

```
banks-own [  
  bank-credits  
  bank-reserves  
  credit-default-prob  
  bank-credit-loss  
  bank-loss-to-pass]
```

The credit protection seller agents are characterized by four variables. One variable relates to the amount of assets that the credit protection seller has (i.e., shares, bonds and other assets), and that the credit protection seller can sell in case of need, e.g., to refund a client bank or another credit protection seller for their losses. Another variable relates to the amount of reserves (as part of equity) that the credit protection seller has, which can be eroded by losses on assets. Another variable relates to the amount of loss on assets that the credit protection seller may suffer at any period of time (and that the credit protection seller may pass to other credit protection sellers, if the credit protection seller has any connections with them, or carry in the income loss of the period, if the credit protection seller has no connections with any other credit protection sellers or if the other credit protection sellers have no means to refund the credit protection seller for the loss). Finally, another variable relates to the amount of loss on assets that the credit protection seller can pass to other credit protection sellers. This is implemented with the following code:

```
cpss-own [  
  cps-assets  
  cps-reserves
```

```
cps-assets-loss  
cps-loss-to-pass]
```

Model B also includes the central counterparts type of agents. Also the central counterparts agents are characterized by four variables. One variable relates to the amount of assets that the central counterparts has (i.e., shares, bonds and other assets), and that the central counterparts can sell in case of need, e.g., to refund a client credit protection seller for their losses if the other credit protection seller of the credit protection contract does not fulfill the obligation). Another variable relates to the amount of reserves (as part of equity) that the central counterparts has, which can be eroded by losses on assets. Another variable relates to the amount of loss on assets that the central counterparts should pass to the other credit protection seller of a credit protection contract, if the credit protection seller counterpart has assets, but which could affect the income of the period of the central counterpart if the other credit protection seller of a credit protection contract has no means to fulfill its obligation. Finally, another variable relates to the amount of loss on assets that the central counterparts can pass to the other credit protection seller of a credit protection contract. This is implemented with the following code:

```
ccps-own [  
  ccp-assets  
  ccp-reserves  
  ccp-assets-loss  
  ccp-loss-to-pass]
```

The final step of the setup of the model consists of the creation of the agents and the attribution of initial values to the variables. The creation of the bank type of agents and the attribution of initial values to their variables is implemented with the following code:

```
create-banks bank-count [  
  set shape "circle"  
  set color red  
  set bank-credits 30 + random 70  
  set bank-reserves 10 + random 20  
  set bank-credit-loss 0
```

```

set bank-loss-to-pass 0
ifelse prob-default-loan = 0 [set credit-default-prob 0] [set credit-default-prob ((prob-
default-loan - 1) * 10 + random 10)]
move-to one-of patches]

```

The code creates the number of bank agents that is defined by the researcher in the input panel of the model (the variable named bank-count). Each bank agent is represented as a red circle that is placed in a two-dimensional space. The amount of initial credits of each bank is set between 30 and 100 (the random function returns a random integer where each number has the same likelihood). The amount of initial reserves of each bank is set between 10 and 30. The maximum value of credits and reserves is arbitrary, and is merely intended to replicate the assumed tendency of banks to hold credits for a larger amount than reserves. Each bank, moreover, is exposed to bank-specific credit default risk, that is calculated with a formula that depends on an indicator of exposure to credit default risk, that is defined by the researchers in the input panel of the model (the variable named prob-default-loan). The formula converts the indicator (whose value range between 0 and 10) to the probability scale (i.e., values between 0% and 100%).

The creation of the credit protection seller type of agents and the attribution of initial values to their variables is implemented with the following code:

```

create-cpss cps-count [
  set shape "circle"
  set color blue
  set cps-assets 30 + random 70
  set cps-reserves 10 + random 20
  set cps-assets-loss 0
  set cps-loss-to-pass 0
  move-to one-of patches]

```

The code creates the number of credit protection seller agents that is defined by the researcher in the input panel of the model (the variable named cps-count). Each credit protection seller agent is represented as a blue circle that is placed in the same two-dimensional space. The amount of initial credits of each credit protection seller is set between 30 and 100 and the amount of initial reserves of each credit protection seller is set

between 10 and 30. Again, the maximum value of assets and reserves is arbitrary, and is merely intended to replicate the assumed tendency of credit protection seller to hold assets for a larger amount than reserves.

Finally, the creation of the central counterpart type of agents and the attribution of initial values to their variables is implemented with the following code:

```
create-ccps ccp-count [  
  set shape "circle"  
  set color green  
  set ccp-assets 60 + random 140  
  set ccp-reserves 20 + random 40  
  set ccp-assets-loss 0  
  set ccp-loss-to-pass 0  
  move-to one-of patches]
```

The code creates the number of central counterpart agents that is defined by the researcher in the input panel of the model (the variable named `ccp-count`). Each central counterpart agent is represented as a green circle that is placed in the same two-dimensional space. The amount of initial assets of each central counterpart is set between 60 and 200 and the amount of initial reserves of each central counterpart is set between 20 and 60. The maximum values of assets and reserves of the central counterparts are again arbitrary, and their amount relates to the assumed tendency of central counterparts to act as sources of guarantee and stability to the network of credit protection contracts and therefore to hold relatively larger amount of assets and reserves than other financial institutions.

The creation of the networks between the agents is implemented with code that makes actors establish connections with others. The model includes additional inputs that the researcher can set about the connectivity of the banks with credit protection sellers and of credit protection sellers with each other (in Model B, the connection between credit protection sellers takes place through the intermediary role of the central counterpart, however). The network of banks with credit protection sellers is implemented with the following code:

```
ask banks [create-bank_cps-with one-of cpss]
```

```
repeat bank-connectivity [ask banks [if random 100 < bank-credits [create-bank_cps-with one-of cpss]]]
```

Each bank is required to establish a connection with one credit protection seller. In addition, depending on the value of the input variable of the connectivity of banks (the variable named bank-connectivity, that ranges between 0 and 10), each bank is required to establish additional connections with other credit protection sellers. Also, the code makes banks more likely to establish additional connections the higher the amount of credits that the bank has, because of the assumed tendency of banks to seek more credit protection contracts the more credits they have towards clients.

In Model A, the network of credit protection sellers is implemented with the following code:

```
ask cpss [create-cps_cds-with one-of other cpss]  
repeat cps-connectivity [ask cpss [if random 100 > cps-assets [create-cps_cds-with one-of other cpss]]]
```

Each credit protection seller is required to establish a connection with another credit protection seller. In addition, depending on the value of the input variable of the connectivity of credit protection sellers (the variable named cps-connectivity, that ranges between 0 and 10), each credit protection seller is required to establish additional connections with other credit protection sellers. Also, the code makes credit protection sellers more likely to establish additional connections the lower the amount of assets that the credit protection seller has, because of the assumed tendency of credit protection seller to seek more credit protection contracts if they have relatively less assets at disposal to fulfill their obligations.

In Model B, instead, the network of credit protection sellers is implemented with the following code:

```
ask cpss [create-cps_ccp-with one-of ccps]  
repeat cps-connectivity [ask cpss [if random 100 > cps-assets [create-cps_ccp-with one-of ccps]]]
```

In this scenario, each credit protection seller is required to establish a connection with a central counterpart. In addition, depending on the value of the input variable of the connectivity of credit protection sellers (the variable named cps-connectivity, that ranges between 0 and 10), each credit protection seller is required to establish additional connections with other central counterparts. Again, the code makes credit protection sellers more likely to establish additional connections the lower the amount of assets that the credit protection seller has, because of the assumed tendency of credit protection seller to seek more credit protection contracts if they have relatively less assets at disposal to fulfill their obligations.

6.3 The Routines of the Model

The model includes a limited number of routines that are intended to make agents carry out some behavior according to rules and conditions that are checked for each and single agent. Routines include those to check whether agents should exit the industry because of bankruptcy, to make agents seek connections when they have run out of connections, to check whether any credit default event affects banks, credit protection sellers, and (in Model B) central counterparts, to compute the reduction of reserves because of loss on income of the period, and to let agents carry out their business with related increase of credits and assets over time. Each of these routines is described in turn.

Exit from the industry

The routines to check whether an agent should exit the industry because of bankruptcy consists of the elimination of agents when their bank reserves are nil or negative. The reduction of reserves of a bank to zero or to a negative value may take place when a bank incurs some losses on the income of the period because of a credit default that the bank cannot pass to any of the connected credit protection sellers because they do not have assets to liquidate to refund the bank for the losses. In Model A, the reduction of reserves of a credit protection seller to zero or to a negative value may take place when a credit protection seller incurs some losses on the income of the period because of the requirement to refund a bank or another credit protection seller, on the basis of a credit protection contract, but the credit protection seller cannot pass the loss to another credit protection seller (because of lack of other swap contract or because other counterparts of swap contracts do not have enough assets). In Model B, also the reserves of a central counterpart can be reduced to zero or to a negative value, when the central counterpart cannot pass the loss on a credit protection contract from one credit protection seller to the counterpart of the

swap and therefore the central counterpart is required to refund the loss (i.e., acting as a guarantor of the credit protection contracts) but has no enough assets to sell. These routines are implemented with the following code:

```
ask banks [if bank-reserves <= 0 [die]]
ask cpss [if cps-reserves <= 0 [die]]
ask ccps [if ccp-reserves <= 0 [die]]
```

Establishment of connections

The routines to establish connections (i.e., credit protection contracts) are intended to check whether any agent has lost all of the connections with other agents and, in the case, to recreate some of them. The loss of all connections may take place if all other counterparts of an agent have exited the industry. If an agent is left without connections, then at least new connection is created (e.g., a bank seeks a connection with a credit protection seller and, in Model A, a credit protection seller seeks a connection with another credit protection seller; in Model B, a credit protection seller seeks connection with another credit protection seller through a central counterpart). Additional connections are created, moreover, depending on input variables related to the connectivity of the bank and credit protection seller networks. These routines are implemented with the following code:

For the network of banks:

```
if count my-bank_cpss = 0 [
  if count cpss > 0 [
    if bank-credits > 0 [
      create-bank_cps-with one-of cpss
      repeat bank-connectivity [if random 100 < bank-credits [create-bank_cps-with one-of
cpss]]
    ]]]
```

For the network of credit protection sellers in Model A:

```
if count my-cps_ccps = 0 [
  if count cpss > 1 [
    if cps-assets > 0 [
```

```

ask one-of cps [create-cps_ccp-with myself create-cps_ccp-with one-of other cps]
if count cps > cps-connectivity + 2 [
  repeat cps-connectivity [if random 100 > cps-assets [ask one-of cps [create-cps_ccp-
with myself create-cps_ccp-with one-of other cps]]]
]]]

```

For the network of credit protection sellers and central counterparts in Model B:

```

if count my-cps_ccps = 0 [
  if count cps > 1 [
    if cps-assets > 0 [
      ask one-of cps [create-cps_ccp-with myself create-cps_ccp-with one-of other cps]
      if count cps > cps-connectivity + 2 [
        repeat cps-connectivity [if random 100 > cps-assets [ask one-of cps [create-cps_ccp-
with myself create-cps_ccp-with one-of other cps]]]
      ]]]]
]]]

```

Checking credit default events

The routines for checking credit default events consist of the occurrence of random credit defaults that determine losses on banks or on credit protection sellers. The occurrence of a credit default event is determined in relation to the probability that a default may happen. The probability is determined, in turn, by two input variables set by the researcher, that relate to a general likelihood of credit defaults events (that may hit all banks at the same time) and of bank-specific credit default events. If a credit default event takes place, then any bank incurs a loss on credits that is dependent on the incidence of the loss, which is set as another input variable by the researcher (the presence of these input variables is relevant to run simulations under different scenario conditions).

When a loss on credits takes place, if a bank has connections (i.e., credit protection contracts) with credit protection sellers then, if a credit protection seller has any assets, then the bank can pass the loss on credits to the credit protection seller – else, it is the bank that incurs the loss on the income of the period. In Model A, the credit protection seller, in turn, checks whether any of the other credit protections sellers that it is connected to has any assets and, in the case, the credit protection seller can pass the loss to the other credit protection seller – else, it is the credit protection seller that incurs the loss on the income of

the period. In Model B, instead, the credit protection seller checks whether any of the other credit protection sellers that it is connected to through any central counterparts has any assets and, in the case, the credit protection seller can pass the loss to the other credit protection seller – else, if the central counterpart has any assets, than it is the central counterpart that refunds (as guarantor) the credit protection seller. If, however, also the central counterpart has no assets then the credit protection seller has to incur the credit loss on the income of the period. These routines are implemented with the following code:

For checking credit default events with banks:

```

if bank-credits > 0
  [if random 100 < (credit-default-prob / 2 + (general-default-risk * 10) / 2)
    [set bank-credit-loss (bank-credits * default-incidence / 100)
      ifelse count my-links > 0
        [set bank-loss-to-pass bank-credit-loss
          ifelse not any? bank_cps-neighbors with [cps-assets > 0]
            [set bank-credits (bank-credits - bank-credit-loss)]
            [ask one-of bank_cps-neighbors with [cps-assets > 0]
              [set cps-assets-loss [bank-loss-to-pass] of myself]]]
          [set bank-credits (bank-credits - bank-credit-loss)]
          set bank-credits 0 ;; set credits of the bank to zero]]
set bank-credit-loss 0
set bank-loss-to-pass 0

```

For checking losses on assets with the credit protection sellers in Model A:

```

if cps-assets > 0
  [if cps-assets-loss > 0
    [ifelse count my-links > 0
      [set cps-loss-to-pass cps-assets-loss
        ifelse not any? cps_cds-neighbors with [cps-assets > 0]
          [set cps-assets (cps-assets - cps-assets-loss)]
          [ask one-of cps_cds-neighbors with [cps-assets > 0]
            [set cps-assets cps-assets - [cps-loss-to-pass] of myself]]]

```

```

    [set cps-assets (cps-assets - cps-assets-loss)]]]
set cps-assets-loss 0
set cps-loss-to-pass 0

```

For checking losses on assets with the credit protection sellers and the central counterparts in Model B:

```

if cps-assets > 0
  [if cps-assets-loss > 0
    [ifelse count my-links >
      [set cps-loss-to-pass cps-assets-
        ifelse not any? cps_ccp-neighbors with [ccp-assets > 0]
          [set cps-assets (cps-assets - cps-assets-loss)]
          [ask one-of cps_ccp-neighbors with [ccp-assets > 0]
            [set ccp-assets-loss [cps-loss-to-pass] of myself
              check-ccp-losses]]]]
    [set cps-assets (cps-assets - cps-assets-loss)]]]
set cps-assets-loss 0
set cps-loss-to-pass 0

```

Where ‘check-ccp-losses’ is the following sub-routine:

```

ifelse any? cps_ccp-neighbors with [cps-assets > 0]
  [set ccp-loss-to-pass ccp-assets-loss
    ask one-of cps_ccp-neighbors with [cps-assets > 0]
      [set cps-assets (cps-assets - [ccp-loss-to-pass] of myself)]]]
  [set ccp-assets (ccp-assets - ccp-assets-loss)]
set ccp-assets-loss 0
set ccp-loss-to-pass 0

```

Computing losses of the income of the period on the reserves

The routines for computing losses of the income of the period on the reserves consist of reducing reserves of agents to take into account the loss of credits or assets because of

losses related to credit default events (or to losses incurred by banks that credit protection sellers should refund). These routines are implemented with the following code:

```
if bank-credits < 0
  [set bank-reserves (bank-reserves + bank-credits)
   set bank-credits 0]
```

```
if cps-assets < 0
  [set cps-reserves (cps-reserves + cps-assets)
   set cps-assets 0]
```

```
if ccp-assets < 0
  [set ccp-reserves (ccp-reserves + ccp-assets)
   set ccp-assets 0]
```

Regaining some credits and assets over time

Finally, these routines consist of the steady increase of credits of banks and of assets of credit protection sellers and central counterparts over time, up to a limit arbitrary set at three times the amount of reserves that agents have. These routines relate to the assumed tendency of financial institutions to grow their investment portfolio. In the simulation of the model, these routines enable agents that have lost all or part of their credits or assets to slowly regain a higher volume of credits or assets. These routines are implemented with the following code:

For the banks:

```
if bank-credits < (bank-reserves * 3) [
  set bank-credits (bank-credits + 10)]
```

For the credit protection sellers:

```
if cps-assets < (cps-reserves * 3) [
  set cps-assets (cps-assets + 10)]
```


And, in Model B, for the central counterparts:

```
if ccp-assets < (ccp-reserves + 3) [  
    set ccp-assets (ccp-assets + 10)]
```

6.4 The Input and Output Interface of the Model

The model also includes an input and output interface, that enable the researcher to set alternative values for input variables of the model (therefore, to simulate the model under different conditions of the scenario) and to observe the aggregated results of the simulation. The input interface consists of devices ('sliders') that enable the researcher to alter input variables in a convenient way. Sliders include control of the following input variables:

Number of banks ("bank-count"): this input variable ranges between 1 and 50

Number of credit protection sellers ("cps-count"): this input variable ranges between 1 and 20

Connectivity of banks ("bank-connectivity"): this input variable affects the number of connections that banks establish with credit protection sellers (it is an indicator that ranges between 0 and 10)

Connectivity of credit protection sellers (cps-connectivity"): this input variable affects the number of connections that credit protection sellers establish with other credit protection sellers (it is an indicator that ranges between 0 and 10)

General exposure to credit default risk ("general-default-risk): this input variable affects the likelihood that all bank experience credit default events (it is an indicator that ranges between 0 and 10)

Bank-specific exposure to credit default risk ("prob-default-loan"): this input variable affects the specific likelihood that any bank experiences credit default event (it is an indicator that ranges between 0 and 10)

Incidence of the default event (“default-incidence”): this input variable affects the extent of losses of credit defaults events, i.e., the percentage of credits that is lost if a default event happens (it is an indicator that ranges between 0 and 100).

In Model B, sliders also include the following input variable:

Number of central counterparts (“ccp-count”): this input variable ranges between 1 and 5.

Figure 1 shows how the set of sliders look like in Model B.

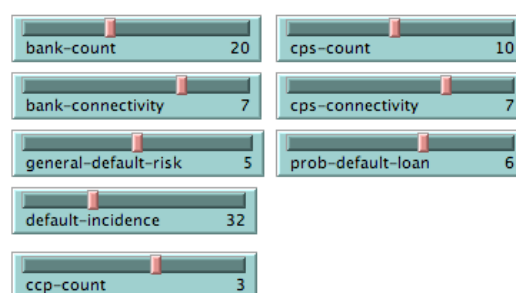


Figure 1. The set of sliders in the input interface of the model (Model B)

The output interface includes value indicators, plots, and the graph of the networks between banks and credit protection sellers (and, in Model B, also central counterparts). Value indicators show relevant aggregated indicator such as:

Total number of banks

Total number of credit protection sellers

Total number of connections between banks and credit protection sellers

Total number of connections between credit protection sellers

Total value of credits of banks

Total value of reserves of banks

Total value of assets of credit protection sellers

Total value of reserves of credit protection sellers.

Figure 2 shows how the set of value indicators looks like:

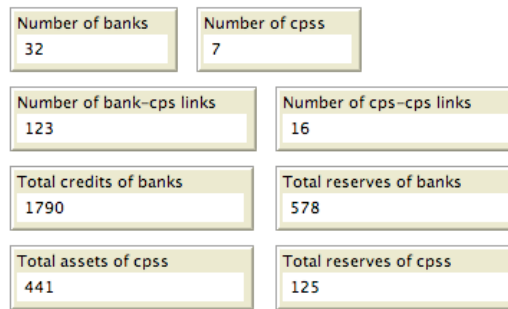


Figure 2. The set of value indicators in the output interface of the model

Plots exhibit how relevant value indicators change over time. Plots are helpful to trace the trajectory of the aggregated behavior of the simulated system. For example, plots can show whether the dynamics of the financial derivatives industry results in a stable configuration (i.e., relatively constant number of banks, credit protection sellers, and total credits, assets, and reserves) or in a change of aggregated values over time. An instance of the plots produced by the simulation of the model is shown in Figure 3.

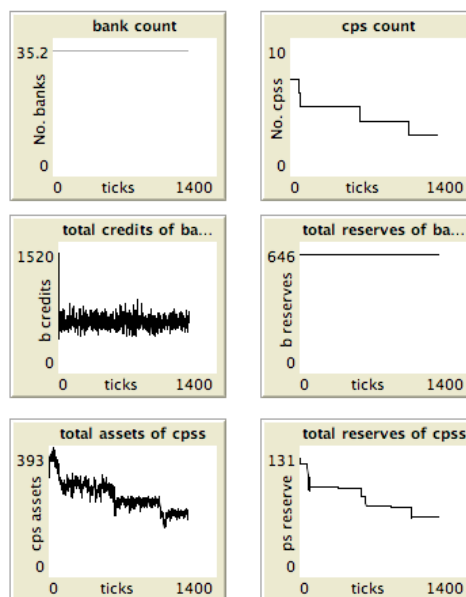


Figure 3. The plots of the model (instance)

Finally, the output interface includes the graph of the network between the agents of the model. The graph includes banks represented as red circles, credit protection sellers represented as blue circles and, in Model B, also central counterparts represented as green circles. Connections take place between banks and credit protection sellers and between credit protection sellers and other credit protections sellers in Model A; and between banks

and credit protection sellers and between credit protection sellers and central counterpart (but not between a credit protection seller and another credit protection seller) in Model B. Moreover, the number of connections between agents depend on the input variables related to the connectivity of the networks. An instance of an initial configuration of the network in Model A is presented in Figure 4, and an instance of an initial configuration of the network in Model B is presented in Figure 5.

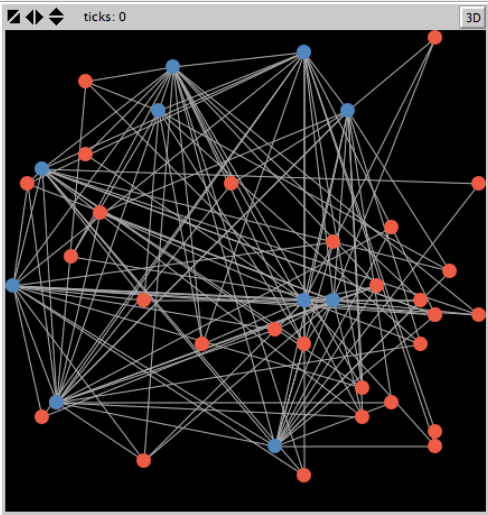


Figure 4. Initial configuration of the network graph in Model A (instance). Banks are represented by red circles and credit protection sellers by blue circles.

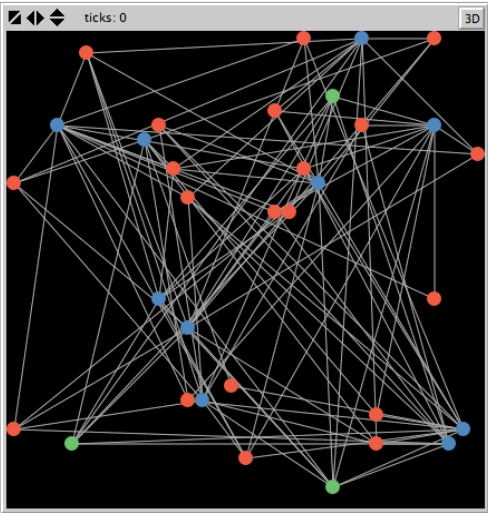


Figure 5. Initial configuration of the network graph in Model B (instance). Banks are represented by red circles, credit protection sellers by blue circles, and central counterparts by green circles.

Chapter 7

The Simulation of the Financial Derivatives Industry

7.1 The Aim of the Simulation

The simulation of the financial derivatives industry aims to enable researchers to gain a qualitative understanding of the dynamics of the industry in relation to alternative features of scenarios, such as a different number of actors in the industry, a different degree of connectivity of the network between these actors, a different exposure to the risk of credit default events, and the presence or absence of central counterparts. It is relevant to highlight that the effects on the aggregated industrial behavior and structure of alternative features of scenarios are not so self-evident, on the basis of how the model has been constructed. The number and kind of relationships between agents of the model is such that it is generally difficult for an analyst to draw deductive inferences of how the simulated system behaves, on the basis of the formulas and commands implemented in the code only. In addition, random components of the model make it harder to figure out how precisely how the system behaves, especially taking into consideration that the networked nature of the simulated industry makes the behavior of agents highly dependent on the patterns of the connections that they have with other agents. It is necessary, therefore, to resort to the computational simulation of the model to collect some evidence of the behavior of the simulated financial derivatives industry.

The rest of the chapter is organized as follows. First, we will report the results of the simulations run on Model A while exploring the behavior of the model when input variables are changes (especially, when they are set at the minimum and maximum values). Then, we will report the results of the simulations run on Model B – that is, when the financial derivatives network includes central counterparts. Finally, we will contrast and compare the results obtained from simulations of Model A and Model B.

7.2 The Simulation of Model A (without Central Counterparts)

The analysis of the behavior of the model of financial derivatives industry starts with the simulation of the model while all input variables are set at intermediate levels of the arbitrary scales that have been set. Under these conditions (number of banks = 25; number

of credit protection sellers = 10; connectivity of banks = 5; connectivity of credit protection sellers = 5; indicator of probability of general credit default = 5; indicator of probability of bank-specific credit default = 5; and incidence of the default = 5), the results of the simulation exhibits some of the typical features of complex systems: in some simulations the system is relatively stable, while in other cases the system is suddenly disrupted by changes that result in the reconfiguration of the simulated financial derivatives industry and, relatedly, to the exit of some players (banks and/or credit protection sellers) from the industry and the reduction of credit activity, or assets, or reserves (or more than one of these features of the agents). An instance of a relatively stable behavior of the system is provided in Figure 1, where an example of a disrupted system is provided in Figure 2.

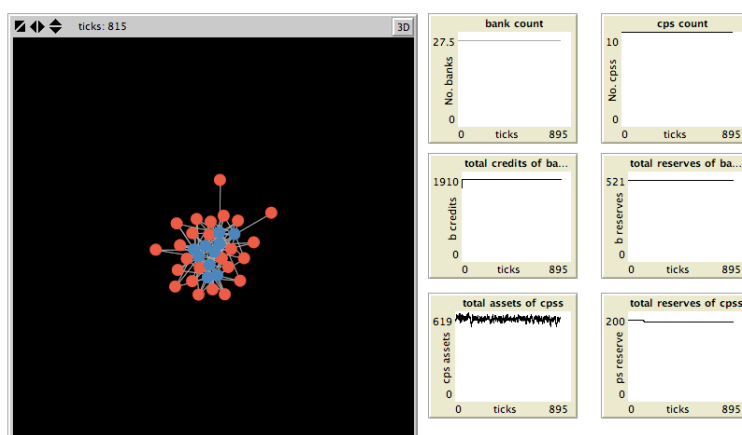


Figure 1. Relatively stable aggregated behavior of the system, with average values of input variables of the model (instance). The system is stable after more than 800 periods ('ticks')

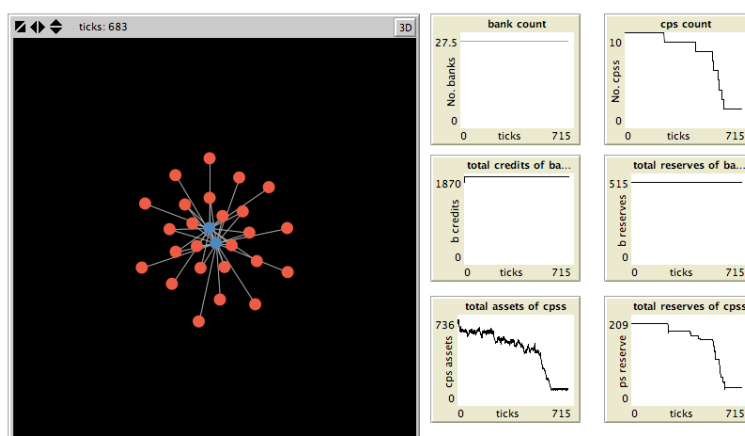


Figure 2. Disrupted aggregated behavior of the system, with average values of input variables of the model (instance). The system went through a disruption and regained stability after about 700 periods ('ticks')

These simulation results indicate that the model of the financial derivatives industry is relatively ‘open ended’ to different possible trajectories. The model is not deterministic as it includes some random components, which especially relate to the randomness included in the initial values of some features of the agents – such as amount of credits, assets, and reserves – and to the configuration of the original network. This feature of the aggregated behavior of the system seems relevant with respect to the conduct of financial derivatives industries: indeed, as the Great Financial Crisis showed, the industry of financial derivatives can be relatively stable over time, but occasionally it may be disrupted in ways that reconfigure the number of actors and their relationships.

If the input variables of the model include relatively low number of banks (Number of banks = 10), *ceteris paribus*, then the aggregated behavior of the system is relatively stable over time (Figure 3). An interpretation of these results is that, with relatively few banks with respect to the number of credit protection sellers, any credit default loss can be easily ‘absorbed’ by the network of credit protection contracts. If the model is set at a relatively high number of banks (Number of banks = 50), instead, then – *ceteris paribus* – the system may experience some disruptions before reaching a stable arrangement at a lower number of credit protection sellers (Figure 4). An interpretation of these results is that, with relatively many banks with respect to the number of credit protection sellers, credit default losses are more likely to erode assets of a particular credit protection seller and therefore making it bankrupt (especially if, because of the particular and random pattern of connections, several credit defaults happen to hit the same credit protection seller).

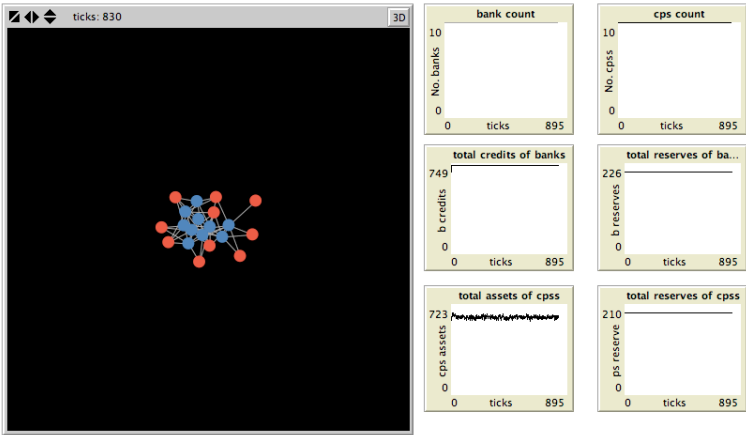


Figure 3. Relatively stable aggregated behavior of the system, with relatively low number of banks at the outset (instance). The system is stable after more than 800 periods (‘ticks’)

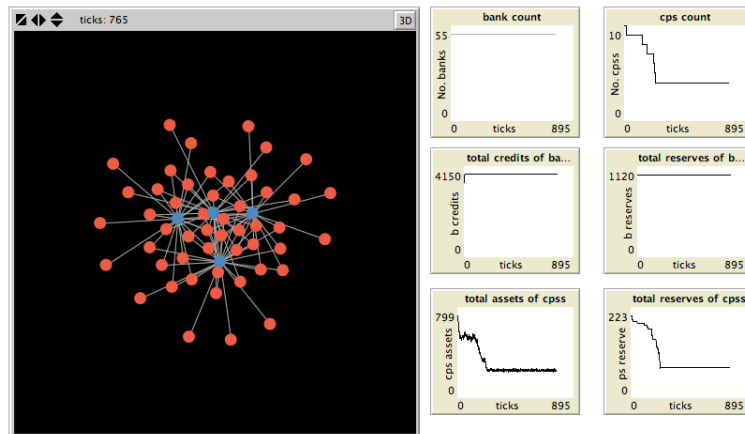


Figure 4. Disrupted aggregated behavior of the system, with relatively high number of banks at the outset (instance). The system went through a disruption and regained stability after about 200 periods ('ticks'), with a lower number of credit default sellers than at the outset.

The simulation also shows that the aggregated behavior of the system is relatively little sensitive – *ceteris paribus* – to the number of credit protection sellers instead. If the input variable of the number of credit protection sellers is set to a relatively low value (e.g., 2) or high value (e.g., 20), the simulation results in relatively stable configurations (while the number of banks is kept at a relatively average level, i.e., 25). An interpretation of these results is that any number of credit protection sellers can arguably confront a moderate amount of credit default losses. It is relevant, instead, to highlight the different behavior of the system under extreme joint condition related to the number of banks and credit protection sellers. If the input variables of the model include both high number of banks (50) and high number of credit protection sellers (25), then the system is exposed to some moderate disruption but it can promptly regain stability (Figure 5). If the input variables of the model include both low number of banks (10) and low number of credit protection sellers (2), then the system looks stable and hardly disrupted (Figure 6). An interpretation of these results is that – not surprisingly – in a relatively ‘small world’ made of a few banks and credit protection sellers, if there are moderate credit defaults then financial institutions do not incur any serious risk of large losses; in a highly fragmented system populated by relatively many actors, instead, it may happen that multiple credit default losses hit the same financial institutions and result in some of them going bankrupt.

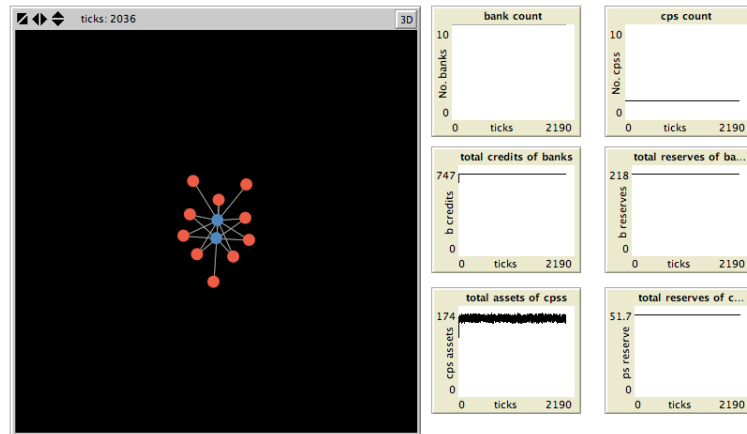


Figure 5. Relatively stable aggregated behavior of the system, with relatively low number of banks and of credit protection sellers at the outset (instance). The system is stable after more than 2,000 periods ('ticks')

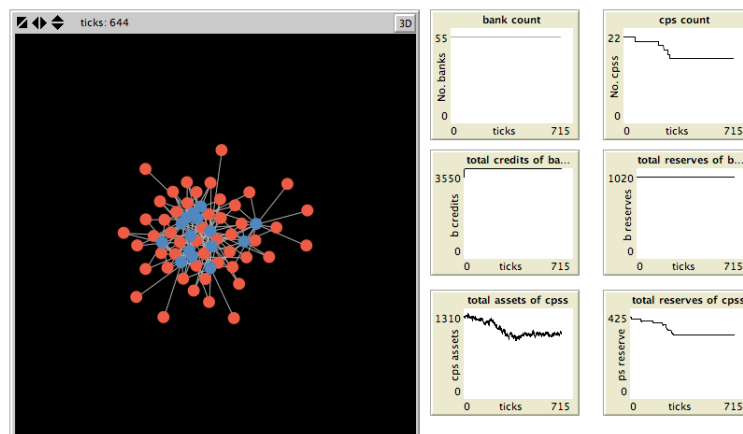


Figure 6. Moderately disrupted aggregated behavior of the system, with relatively high number of banks and credit protection sellers at the outset (instance). The system went through a moderate disruption and regained stability after about 400 periods ('ticks'), with a lower number of credit default sellers than at the outset.

If the input variables of the model include – *ceteris paribus* – high level of connectivity of banks (i.e., index of connectivity of banks = 10), then the system exhibits sources of instability that result in the reconfiguration of the industry at lower number of credit protection sellers (Figure 7). In some simulations, the financial derivatives industry may be relatively stable for some periods, but – if enough time is allowed – disruptions may occur. An interpretation of these results is that the high level of connectivity (i.e., number of credit protection contracts, like swaps) between banks and credit protection sellers results in making the system more exposed to the risk that a random concentration of credit defaults results in losses on particular credit protection sellers. A relevant insight

from these results is also that disruptions to the system may originate ‘suddenly’ even in period when the system seems to have reached an apparent stability.

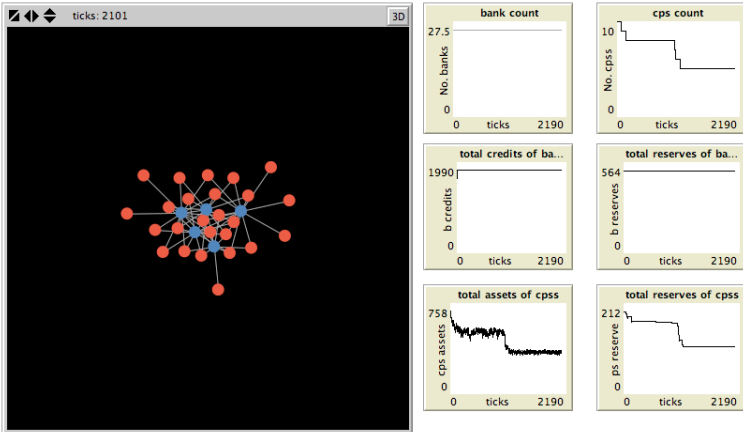


Figure 7. Occasionally disrupted aggregated behavior of the system, with relatively high level of connectivity between banks and credit protection sellers (instance). The system may experience sudden disruptions between periods of relative stability.

If the input variables of the model include – *ceteris paribus* – low level of connectivity of banks instead (i.e., index of connectivity of banks = 0), then the system can be disrupted in ways that force most of credit protection sellers out of the industry (Figure 8). An interpretation of these results is that the low level of connectivity (i.e., number of credit protection contracts, like swaps) between banks and credit protection sellers results in making the system exposed to the risk that any random credit default (or a few subsequent credit defaults) that hit a particular bank can result in losses on the particular credit protection seller of the bank. A stable configuration may be reached (for example, with only two credit protection sellers left) depending on whether the occurrence of credit default losses is moderate and compensated by the assumed tendency of the credit protection sellers to regain some assets for the continuation of their business activity.

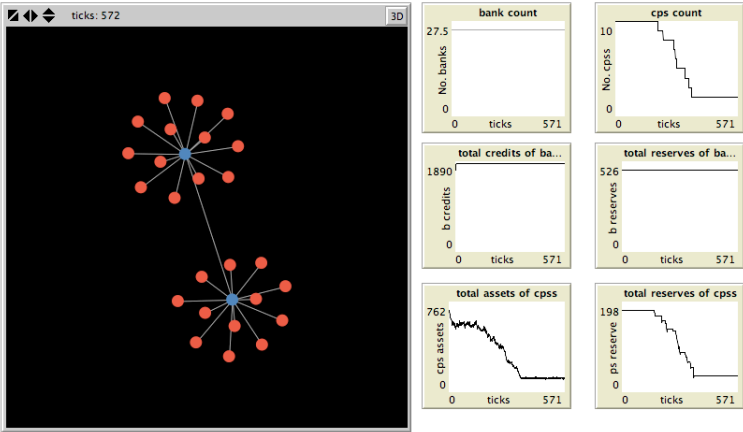


Figure 8. Disrupted aggregated behavior of the system, with relatively low connectivity between banks and credit protection sellers at the outset (instance). The system went through a disruption and regained stability after about 300 periods ('ticks'), with a lower number of credit default sellers than at the outset.

Additional relevant insights are gained from the manipulation of the input variable related to the connectivity of the credit protection sellers. If the indicator of connectivity of credit protection sellers is set to high level (10), then the system – *ceteris paribus* – may be disrupted and regain stability at a lower number of credit protection sellers, but it is noticeable that disruption takes place after a considerable longer period of time than at a lower level of connectivity of credit protection sellers (Figure 9). An interpretation of these important results is that, if the simulated financial derivatives industry includes high level of connectivity between credit protection sellers, then credit default losses can be 'attenuated' within the network of credit protection contracts and result in a relatively 'dispersed' impact on the assets (and reserves) of the credit protection sellers – which are, therefore, in the position to keep operating in the industry for relatively longer time periods than in scenarios where they have less protection for their losses from other credit protection sellers.

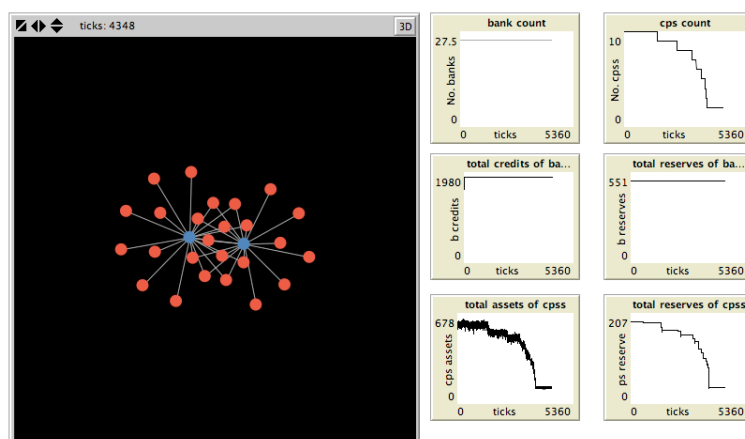


Figure 9. Disrupted aggregated behavior of the system, with relatively high connectivity between credit protection sellers at the outset (instance). The system went through a disruption that took place relatively slowly and after a relatively long period of stability (about 1.500 'ticks'), resulting in a lower number of credit default sellers than at the outset.

The scenario where the connectivity of the credit protection sellers – *ceteris paribus* – is relatively low (0), instead, results in a quite different outcome. The system, in this case, tends to exhibit a disruption that takes place relatively quickly and rapidly and that results in a lower number of credit protection sellers than at the outset. We can interpret these results by arguing that, if credit protection sellers are relatively little connected with

each other, than a random credit default (or a few subsequent credit defaults) can rapidly force a credit protection seller out of the industry.

Not surprisingly, input variables that relate to the probability of credit defaults (both general and bank-specific) have important effects on the aggregated behavior of the system. High levels of probability of credit default result – *ceteris paribus* – in the rapid erosion of assets and reserves of several credit protection sellers, while low levels of probability of credit default may result – *ceteris paribus* – in relative stability of the system. Also not surprisingly, the incidence of credit default (i.e., the percentage of credits of a bank that are lost if the bank is hit by a credit default event) also affects the behavior of the system, where relatively high incidence (e.g., default incidence = 30% or more) results – *ceteris paribus* – in the rapid extinction of all credit protection sellers (Figure 10) while relatively minimal incidence results – *ceteris paribus* – in the preservation of the original industrial structure.

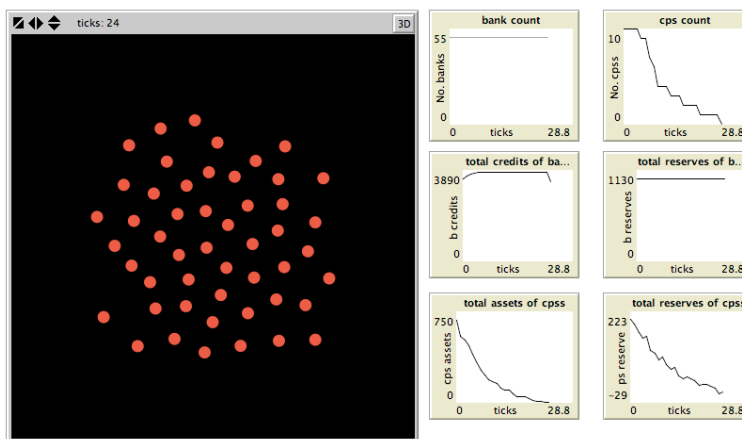


Figure 10. Total extinction of credit protection sellers when the incidence of credit default events is relatively high (instance). All credit protection sellers went bankrupt in a relatively short time period (about 30 ‘ticks’).

7.3 The Simulation of Model B (with Central Counterparts)

The analysis of the behavior of the model of financial derivatives industry when the industry includes central counterparts provides some insightful results. First, we review the results of the simulation the model while all input variables are set at intermediate levels of the arbitrary scales that have been set (number of banks = 25; number of credit protection sellers = 10; connectivity of banks = 5; connectivity of credit protection sellers = 5; indicator of probability of general credit default = 5; indicator of probability of bank-specific credit default = 5; and incidence of the default = 5). Under these conditions, the

results of the simulation are consistently stable, i.e., the simulated industry retains the same number of actors that are set at the outset (Figure 11). These results are strikingly different from those obtained from the simulation of Model A under the same conditions, where the simulated financial derivatives industry exhibited the typical traits of complex systems with either stable patterns or sudden disruptions that result in a lower number of actors. These results can be interpreted as a confirmation of the functional role of central counterparts to enhance the stability of the financial derivatives industry, at least in the conditions that are set at the average values of the input variable scales.

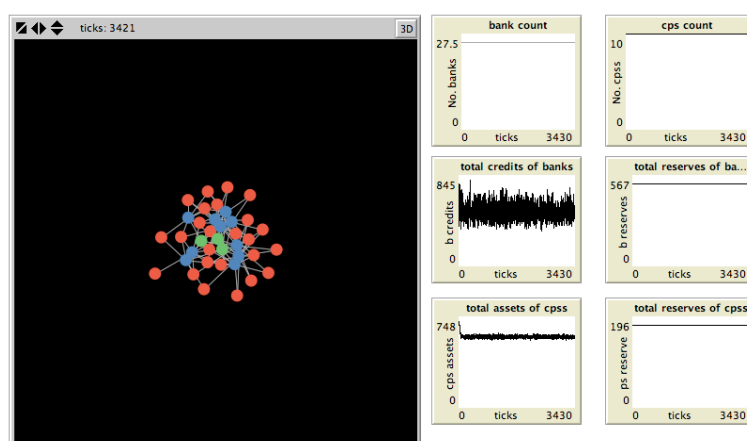


Figure 11. Relatively stable aggregated behavior of the system in Model B, with average values of input variables of the model (instance). The system is stable after more than 3,000 periods ('ticks')

If the input variables of the model include relatively low number of banks (Number of banks = 10), then the aggregated behavior of the system is relatively stable – *ceteris paribus* – over time. If the Model B is set at relatively high number of banks (Number of banks = 50), then the system still exhibits – *ceteris paribus* – a remarkable stability. Also these results are in contrast with those obtained from the simulation of Model A, where the high number of banks could result in some disruptions before the system reach a stable arrangement at a lower number of credit protection sellers. Again, we can interpret this result in relation to the presumed function of central counterparts to enhance the stability of the financial derivatives industry, that seems to retain the original number of players even if – given the higher number of banks – the sources of instability that originate from credit default events are higher.

Similarly to Model A, also Model B results in a simulation where the aggregated behavior of the system is relatively little sensitive – *ceteris paribus* – to the number of credit protection sellers. Differently from Model A, however, in Model B the system is

stable also when both the number of banks and the number of credit protection sellers are relatively high. In Model B, moreover, the system appears stable also irrespective of the level of connectivity of banks and of credit protection sellers. The behavior of the simulated financial derivatives industry with the central counterparts seems to retain stability even if both levels of connectivity of banks and credit protection sellers are relatively high. If both of their connectivity indicators are low, the system is relatively stable but it may happen that the industry disaggregates into separate networks of credit protection contracts (Figure 12).

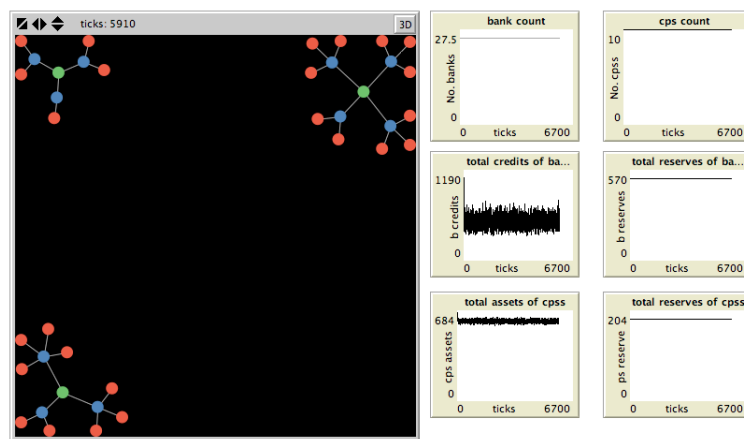


Figure 12. Relatively stable aggregated behavior of the system in Model B, with low values of connectivity of banks and of credit protection sellers (instance). The system results in the disaggregation of the financial derivatives industry into separated networks of credit protection contracts.

A relevant result of the simulation of Model B is that the system remains stable even with relatively high values of the probabilities of credit default events, both generally and bank-specifically. An interpretation of these results is that the simulated financial derivatives industry gains remarkable stability with the inclusion of central counterparts, which are evidently able to assist the execution of credit protection contracts also when it is likely that banks experience default events (either systemically or specifically). Similarly to Model A, however, the aggregated behavior of the system is sensitive to the incidence of credit default events: if the default incidence is higher (e.g., 10% or more rather than 5%) then the system may be disrupted and results in a lower number of credit protection sellers. With respect to the results obtained from Model A, where relatively high levels of default incidence may lead to the extinction of all credit protection sellers, the simulation of Model B provides more comforting conclusions: although the simulated financial derivatives system is seriously hit by relatively high percentage of losses on credits because of default events, the system may result in a relatively stable aggregated behavior at a lower number

of credit protection sellers after the disruption takes place (Figure 13), and only if the default incidence is higher (e.g., 20% or more) then the trajectory of the system may terminate (as in Model A) in the extinction of credit protection sellers.

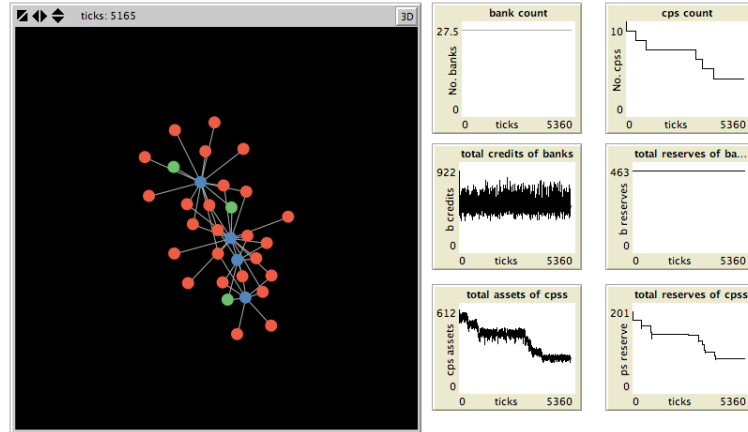


Figure 13. Relatively stable aggregated behavior of the system in Model B after a disruption period, resulting from high incidence of credit defaults (instance).

Last simulation of the model relates to explore the aggregated behavior of the simulated financial derivatives industry when initial conditions of the system include a different number of CCPs. In principle, a financial derivatives industry may include more than one CCP, which could compete with each other in providing central counterpart services. The simulation shows that the number of CCPs does not affect – *ceteris paribus* and in average conditions of the other input variables – the tendency to stability of the system. The number of CCPs does not also seem to affect the aggregated behavior of the system when the incidence of default is relatively higher.

7.4 Comparing Model A and Model B: The Role of Central Counterparts

The simulation of the financial derivatives industry carried out in the two scenarios results in some remarkable differences in the aggregated behavior of the system. Table 1 summarizes the findings of the analysis. A general trait of the comparison is that the model with central counterparts provides more stability to the simulated financial derivatives industry, both under conditions of average value of all input variables of the model and under more extreme scenario conditions. While the model without central counterparts may be disrupted by the occurrence of credit default events in various scenario conditions, in the model with central counterparts it seems that the system possesses the capacity to ‘absorb’ credit default losses and retain the original configuration of the simulated industry.

	Model A (without central counterparts)	Model B (with central counterparts)
Average input variables	Open-ended (either stable or disrupted)	Stable
Number of agents:		
High	Possible disruption followed by regained stability	Stable
Low	Stable ('small world')	Stable
Connectivity between the agents		
High	Possible disruption after some time followed by regained stability	Stable
Low	Prone to disruption in relatively short time	Stable but the industry may disaggregate into separate networks
Probability of credit default events		
High	Prone to disruption followed by regained stability	Stable
Low	Stable	Stable
Incidence of credit defaults		
High	Prone to extinction of credit protection sellers in relatively short time	Prone to disruption followed by regained stability or to extinction of credit protection sellers
Low	Stable	Stable

Table 1. Results from the simulation of Model A and Model B: features of the aggregated behavior of the simulated financial derivatives industry

It should be highlighted, however, that also the model with central counterparts is not immune from potential sources of disruption. Most noticeably, if the simulated financial derivative industry exhibits relatively low level of connectivity between agents, then the credit protection network may disaggregate into smaller and separated networks, each organized around a different central counterpart. This scenario may be not too irrelevant to the actual industrial organization of financial derivatives, where competing central counterparts may contend industry players and, if connectivity is relatively low, may result in segregated networks. Another potential source of disruption for the simulated financial derivatives industry with central counterparts is the exposure to relatively high incidence of default loss, where Model B – similarly to Model A – resulted in disruptions that reduced the number of credit protection sellers operating in the industry. Differently from Model A, however, Model B may not result in the extinction of credit protection sellers, a feature of the outcome of Model B that may corroborate the beliefs that central counterparts result in greater stability of the financial system.

7.5 Some Limitations of the Model

The model of financial derivatives industry presented here has some limitations that should be duly acknowledged. The main limitation of the model originates from a critique that can be addressed towards all agent-based models and, relatedly, to the very simulation methodology: what is the relevance of the model and of the results to ‘real world’ behavior? This question casts the doubt that the results from the simulation may have little to do with actual aggregated behavior of any financial derivatives industry for a number of reasons: wither the model may include drivers of the conduct of agents that are different from those that orient the behavior of industry players; or rules that do not completely correspond to those that are followed in the execution of derivatives contracts; or values for the input variables and other parameters that are not commensurate to the magnitude of the corresponding characteristics of the financial derivatives industry.

This source of criticism is partially well founded, in the sense that the model developed in the present study – like many simulation models generally – does not produce outputs that can be related to any observed properties of any financial derivatives industry. The source of criticism, however, is not really keyed to the point that the model aims to attain, namely, to a qualitative understanding of the system dynamics of the financial derivatives industry rather than estimating empirical properties of actual financial derivatives industry. In this respect, the model fulfills its function to provide some valuable insights into the regulation of financial derivatives: it provides some evidence, in the form of simulation results, that central counterparts can enhance the stability of the financial derivatives industry, although they do not guarantee that all sources of disruption of the industry are effectively counteracted.

Another limitation of the model is, admittedly, the relative over-simplification of the complexity of the financial derivatives industry, especially in relation to the features of credit protection contracts and the strategic behavior of industry actors. Credit protection contracts are relatively sophisticated institutions, which often include several clauses, terms, and conditions. Replicating such sophistication into the algorithms that determine the allocation of losses among the actors (e.g., banks or credit protection sellers, and in which amount) has not been a central concern of the present study. It is possible, however, that the model presented here can be further developed in order to include more sophisticated – and, in a sense, ‘realistic’ – accounts of contractual practices in the financial derivatives industry. Also the strategic behavior of industry actors has not been completely ‘captured’ by the model presented here: for example, the model does not include any role

for credit protection sellers' strategy for managing their derivatives portfolio, nor any role for entry decisions of potential new competitors in the industry, nor the possibility that industry actors exchange derivatives for speculative purposes (and, relatedly, how this affects market prices). Again, while consideration for these features of the financial derivatives industry might have enhanced the sophistication and the 'realism' of the model, they have not been included for pragmatic reasons – the central concern of having developed the model presented here being to investigate the role of central counterpart as regulatory tools for the financial derivatives industry. Additional developments of the model presented here, however, can certainly include different – and more ingenious – algorithms for simulating the conduct of relevant industry actors.

7.6 Venues for Future Research

The study that has been conducted here is relatively original insofar as it employed the simulation approach (specifically, the agent-based method) for investigating the regulation of the financial derivatives industry. With respect to the scholarly debate on whether and how financial derivatives should be regulated, the present study provides some evidence for corroborating the argument that central counterparts can enhance the stability of the financial derivatives industry, although it also provides some evidence for arguing that, under particular scenario conditions such as relatively low connectivity in the industry and relatively high incidence of default losses, also central counterparts may not effectively guarantee that the financial derivatives industry are immune from serious sources of disruption.

Having said that, the present study also suggests some venues for additional research. First, the present study provides an instance of an agent-based method for simulating the effects of regulatory tools of the financial derivatives industry: as such, the model presented here can set a new benchmark for the development of a class of models intended to investigate – through simulations – the expected effects of alternative regulatory tools. Admittedly, the simulation approach (and in particular the use of agent-based method) is still relatively uncommon within the finance scholarly literature (and it is still relatively marginalized, as other 'heterodox' approaches, within the field of economics). It is argued here, however, that the simulation approach can effectively complement other research strategies – especially theory-driven deductive and empirically-oriented inductive perspectives – for providing a deeper understanding of the behavior of financial systems and assisting the formulation of more effective regulatory policies.

Second, the present study has only focused on the role of central counterparts for regulating the financial derivatives industry. Additional research could be done on the effects of other regulatory tools, especially among those taken into consideration in the present policy cycle – in the aftermath of the Great Financial Crisis – oriented to re-regulating the use of derivatives contract. The agent-based method can offer some promising results, in this respect, mostly if we take into consideration the need for regulatory tools to anticipate the joint effect of decisions taken by actors that strategically interact with each other, the role of unintended consequences, and the possibility that some actors devise ingenious strategies to bypass or circumvent those parts of the regulations that limit (in their perspectives) their profitability. Armed with agent-based method tools, financial regulators may be better positioned to design more effective regulatory tools.

Finally, additional research could be done on the area of the design of policy tools with the aim of engineering innovative instruments for steering the conduct of financial industry actors and, relatedly, of aggregated dimensions of the financial industry, in the desired way. Again, agent-based models can assist the researchers and the regulators because of their capacity to explore emergent strategies of financial industry actors and, if agents are endowed with learning capabilities, to figure out novel ways to tackle coordination and collaboration problems.

Chapter 8

Conclusions

This study aimed to address the issue of how financial derivatives are regulated. The issue gained a prominent relevance during the 2010's, especially in the context of the policy reaction to the Great Financial Crisis that hit the world economy in 2007-08 and whose repercussions – in such terms as, for example, credit shrinkage, increased unemployment, and expansion of public sector debt – reverberated for several years. Part of these policy measures was directed to tackle what was perceived as one of the main (joint) causal sources of the crisis, namely the expansion of a relatively under-regulated financial derivatives industry. Once a relatively marginal financial product that served specialized needs for reducing market operators' exposure to various sorts of risks (e.g., price and currency fluctuations, credit default), in the last decades of the twentieth century financial derivatives gained a prominent role in the global financial system. An intricate network of financial derivatives contracts served both hedging and speculative purposes of several financial operators, although the industry structure included a pivotal role for a few large financial institutions that resulted in the overwhelming – and largely unnoticed and unregulated – concentration of risk. When the Great Financial Crisis exploded, a concatenation of financial derivative contracts led to the emergence of unbearable losses in financial institutions that, because of their high level of interconnectedness with the rest of the industry, could potentially throw the financial systems to the knees.

In the emergent policy debate, alternative viewpoints contended what role financial derivatives play in the preservation of the stability or the amplification of sources of instability of the financial system, whether financial derivatives should be subjected to strict regulatory requirements or their use should be left to the autonomous judgment of financial operators, and how exactly financial derivatives should be regulated. Among the policy tools that policy-makers have proposed – especially at the G20 meeting in 2009 – and that have been introduced in the financial regulation of several countries, an important role is played by Central Counterparts (CCPs). CCPs are financial institutions that operate as counterparts to trades of derivative contracts that take place between market participants:

without CCPs, two financial operators enter derivative contracts with each other; with CCPs, each of two financial operators enter respective derivative contracts with the CCP, which takes an intermediary role between the parties. CCPs perform various functions, including the possibility to monitor derivatives trade between parties, supervise the execution of derivative contracts, and act as ‘guarantor’ that financial obligations will be duly fulfilled. As such, CCPs are believed to improve the stability of the financial system, especially by containing the diffusion of losses from one financial operator to another and therefore ‘absorbing’ or ‘cushioning’ the impact of the risk events covered by the derivatives contracts.

While the argument for the stabilizing role of CCPs is persuasive, CCPs may not fully protect the financial system from painful disruptions, which may take place depending on the conditions of the financial derivative industry. This study exactly aimed to address the questions of whether CCPs are able to effectively perform a stabilizing role when facing some of the actual conditions under which financial market operate, e.g., the high level of connectivity between financial institutions (that engage in multiple derivative contracts to hedge their positions and for speculative purposes), the presence of both systemic and institution-specific shocks, and the possibility that relatively large defaults impair the stability of the whole financial system. These questions have been addressed using a simulation approach based on agent-based modeling methodology, that is especially suited to investigate the aggregated behavior of complex system such as the financial derivatives industry. The complexity of the financial derivatives industry arises from several of the features of this part of the financial industry, which particularly include the heterogeneity of the financial derivatives industry actors, the articulation of the structure of the industry in a networked form, and the dynamic nature of the financial derivative industry – where past events have important feedback effects that influence the trajectory of the industry. With respect to alternative methodological approaches – such as hypothesis testing of causal relationship on the basis of industry time series data – agent based models allow researchers to explore the aggregated behavior of a system by contrasting and comparing system behavior under different scenario conditions that are influenced in a quasi-experimental design setting (the difference with an experimental design being, of course, that evidence from simulations is self-generated through the computations of the model rather than collected from controlled testing conditions on empirical subjects).

The results of this study suggest that the introduction of CCPs can assist enhancing the stability of the financial system, although not without potential pitfalls and limitations. A potential pitfall is the possibility that, if financial industry actors are highly interconnected with each other and in the presence of multiple CCPs, then the dynamics of the system may result in the fragmentation of the financial derivative industry into separate derivatives contract networks – a result that may originate from the possibility that a fortuitous concentration of losses makes some financial industry operators refocus their trade with a limited number of CCPs only. A limitation is the possibility that, if the incidence of losses is relatively high, then the occurrence of losses may result in the exit of some financial industry operators and the shrinking of the value of activity of the financial derivatives industry. Because of these results, it is argued here that, even after the introduction of CCPs, financial regulators and public authorities should remain alert of the potential threats to the stability of the financial system.

Appendix

Model A code:

```
;; General features of the model

breed [banks bank] ;; create the banks
breed [cpss cps] ;; create the credit protection sellers

undirected-link-breed [bank_cpss bank_cps] ;; create the network between banks and cpss
undirected-link-breed [cps_cpss cps_cds] ;; create the network between cpss

;; Initialization of the variables

banks-own [
  bank-credits ;; amount of credits that the bank has
  bank-reserves ;; amount of reserves that the bank has
  credit-default-prob ;; probability that a bank suffers from default of its credits
  bank-credit-loss ;; the loss on credits that the bank incurs
  bank-loss-to-pass ;; outflow of loss on credits that the bank wants to pass to a cps
]

cpss-own [
  cps-assets ;; amount of assets the credit protection seller has and can sell in case of need
  cps-reserves ;; amount of reserves that the credit protection seller has
  cps-assets-loss ;; inflow of loss on assets that the cps should try to recover from others
  cps-loss-to-pass ;; outflow of loss on assets that the cps wants to pass to others
]

;; Set-up of the model

to setup
  __clear-all-and-reset-ticks
  setup-banks
  setup-cpss
  network-banks
  network-cpss
end

to setup-banks
  create-banks bank-count [
    set shape "circle"
    set color red
    set bank-credits 30 + random 70
    set bank-reserves 10 + random 20
    set bank-credit-loss 0
    set bank-loss-to-pass 0
    ifelse prob-default-loan = 0 [set credit-default-prob 0] [set credit-default-prob ((prob-
default-loan - 1) * 10 + random 10)]
    move-to one-of patches
```

```
]
end
```

```
to setup-cpss
  create-cpss cps-count [
    set shape "circle"
    set color blue
    set cps-assets 30 + random 70
    set cps-reserves 10 + random 20
    set cps-loss-to-pass 0
    set cps-assets-loss 0
    move-to one-of patches
  ]
end
```

```
to network-banks
  ask banks [create-bank_cps-with one-of cpss]
  repeat bank-connectivity [ask banks [if random 100 < bank-credits [create-bank_cps-with
one-of other cpss]]]
;; Every bank has at least one connection with a cps
;; The higher the connectivity of a bank with cpss, the more banks search for additional
connections with other cpss
;; Searching for connections with other cpss is more likely if the bank has more credits
end
```

```
to network-cpss
  ask cpss [create-cps_cds-with one-of other cpss]
  repeat cps-connectivity [ask cpss [if random 100 > cps-assets [create-cps_cds-with one-of
other cpss]]]
;; Every cps has at least one connection with another cps
;; The higher the connectivity of cpss with each other, the more cpss search for additional
connections with other cpss
;; Searching for connections with other cpss is more likely if the cps has less assets
end
```

```
;; The general routine of the model
```

```
to go
if not any? banks [stop]
if not any? cpss [stop]
```

```
ask banks [if bank-reserves <= 0 [die]] ;;banks fail when they are out of reserves
ask cpss [if cps-reserves <= 0 [die]] ;; cpss fail when they are out of reserves
```

```
ask banks [seek-bank-connections]
ask cpss [seek-cps-connections]
```

```
ask banks [check-bank-losses]
ask cpss [check-cps-losses]
```

```

ask banks [reduce-bank-reserves]
ask cpss [reduce-cps-reserves]

ask banks [restore-bank-credits]
ask cpss [restore-cps-assets]

tick

make-plot
make-plot2
make-plot3
make-plot4
make-plot5
make-plot6
if layout? [layout] ;; This is to run the graphic display of the financial network
end

;; The routines to check if banks and cpss have no more connections

to seek-bank-connections
  if count my-bank_cpss = 0 [ ;; if the bank has no more connections
    if count cpss > 0 [ ;; if there are cpss
      if bank-credits > 0 [ ;; if the bank has credits
        create-bank_cps-with one-of cpss ;; create a connection between the bank and one cps
        repeat bank-connectivity [if random 100 < bank-credits [create-bank_cps-with one-of
cpss]] ;; create additional connections depending on connectivity
      ]]]
    end
end

to seek-cps-connections
  if count my-cps_cpss = 0 [ ;; if the cps has no more connections
    if count cpss > 1 [ ;; if there are other cpss
      if cps-assets > 0 [ ;; if the cps has assets
        create-cps_cds-with one-of other cpss ;; create a connection between the cps and
another cps
        if count cpss > cps-connectivity + 2 [ ;; if there are enough other cpss
          repeat cps-connectivity [if random 100 > cps-assets [create-cps_cds-with one-of
cpss]] ;; create additional connections depending on connectivity
        ]]]]
    end
end

;; The routines to check if there is any default and what are their consequences on the cds
network

to check-bank-losses
  if bank-credits > 0 ;; if a bank has some credits
    [if random 100 < (credit-default-prob / 2 + (general-default-risk * 10) / 2) ;; if it
randomly happens that there is a default
    [set bank-credit-loss (bank-credits * default-incidence / 100) ;; then a loss on credits
happens

```

```

    ifelse count my-links > 0 ;; if there are connections with at least one cps
      [set bank-loss-to-pass bank-credit-loss;; then take note of the loss on credits to pass to
a cps
    ifelse not any? bank_cps-neighbors with [cps-assets > 0] ;; if there are no links to cps
with assets
      [set bank-credits (bank-credits - bank-credit-loss) ;; then compute the loss on credits
of the bank
      ]
      [ask one-of bank_cps-neighbors with [cps-assets > 0] ;; else, then ask any linked cps
with assets...
      [set cps-assets-loss [bank-loss-to-pass] of myself] ;; that the cps takes note of
potential loss on their assets
      ]]
      [set bank-credits (bank-credits - bank-credit-loss)] ;; else, then compute the loss on
credits of the bank
      ]]
    set bank-credit-loss 0 ;; reset losses on credit of the bank as nil
    set bank-loss-to-pass 0 ;; reset losses to pass to cps as nil
end

```

to check-cps-losses

```

    if cps-assets > 0 ;; if a cps has some assets
      [if cps-assets-loss > 0 ;; if the cps has some loss on assets passed by another agent
      [ifelse count my-links > 0 ;; if there are links with other cps
      [set cps-loss-to-pass cps-assets-loss ;; then take note of the loss on assets to pass to
another cps
      ifelse not any? cps_cds-neighbors with [cps-assets > 0] ;; if there are no links to cps
with assets
        [set cps-assets (cps-assets - cps-assets-loss) ;; then compute the loss on assets of the
cps
        ]
        [ask one-of cps_cds-neighbors with [cps-assets > 0] ;; else, then ask any linked cps
with assets...
        [set cps-assets cps-assets - [cps-loss-to-pass] of myself] ;; that the cps takes note of
potential loss on their assets
        ]]
        [set cps-assets (cps-assets - cps-assets-loss)] ;; else, then compute the loss on assets of
the cps
        ]]
      set cps-assets-loss 0 ;; reset losses on assets of the cps as nil
      set cps-loss-to-pass 0 ;; reset losses of the cps to pass as nil
end

```

;; The routines to transfer losses on credits and assets to reserves

to reduce-bank-reserves

```

    if bank-credits < 0 ;; if a bank has negative credits
      [set bank-reserves (bank-reserves + bank-credits) ;; then reduce bank reserves for the
amount of the negative credits
      set bank-credits 0] ;; reset credits to zero

```

end

to reduce-cps-reserves

```
  if cps-assets < 0 ;; if a cps has negative assets
    [set cps-reserves (cps-reserves + cps-assets) ;; then reduce cps reserves for the amount of
the negative assets
    set cps-assets 0] ;; reset assets to zero
end
```

;; Routines to let banks and cps regain some credits and assets over time

to restore-bank-credits

```
  if bank-credits < (bank-reserves * 3) [ ;; if a bank can expand its credits
    set bank-credits (bank-credits + 10) ;; bank credits are slightly increased
  ]
end
```

to restore-cps-assets

```
  if cps-assets < (cps-reserves * 3) [ ;; if a cps can expand its assets
    set cps-assets (cps-assets + 10) ;; cps assets are slightly increased
  ]
end
```

;; The following code draws the plots

to make-plot

```
  set-current-plot "bank count"
  set-current-plot-pen "default"
  plot count banks
end
```

to make-plot2

```
  set-current-plot "cps count"
  set-current-plot-pen "default2"
  plot count cps
end
```

to make-plot3

```
  set-current-plot "total credits of banks"
  set-current-plot-pen "default3"
  plot sum [bank-credits] of banks
end
```

to make-plot4

```
  set-current-plot "total reserves of banks"
  set-current-plot-pen "default4"
  plot sum [bank-reserves] of banks
end
```

to make-plot5

```

set-current-plot "total assets of cps"
set-current-plot-pen "default5"
plot sum [cps-assets] of cps
end

```

```

to make-plot6
  set-current-plot "total reserves of cps"
  set-current-plot-pen "default6"
  plot sum [cps-reserves] of cps
end

```

:: The following code draws the network

```

to layout
  ;; the number 3 here is arbitrary; more repetitions slows down the
  ;; model, but too few gives poor layouts
  repeat 3 [
    ;; the more turtles we have to fit into the same amount of space,
    ;; the smaller the inputs to layout-spring we'll need to use
    let factor sqrt count turtles
    ;; numbers here are arbitrarily chosen for pleasing appearance
    layout-spring turtles links (1 / factor) (7 / factor) (1 / factor)
    display ;; for smooth animation
  ]
  ;; don't bump the edges of the world
  let x-offset max [xcor] of turtles + min [xcor] of turtles
  let y-offset max [ycor] of turtles + min [ycor] of turtles
  ;; big jumps look funny, so only adjust a little each time
  set x-offset limit-magnitude x-offset 0.1
  set y-offset limit-magnitude y-offset 0.1
  ask turtles [ setxy (xcor - x-offset / 2) (ycor - y-offset / 2) ]
end

```

```

to-report limit-magnitude [number limit]
  if number > limit [ report limit ]
  if number < (- limit) [ report (- limit) ]
  report number
end

```

Model B code

```
:: General features of the model
```

```
breed [banks bank] ;; create the banks  
breed [cpss cps] ;; create the credit protection sellers  
breed [ccps ccp] ;; create the central counterparts
```

```
undirected-link-breed [bank_cpss bank_cps] ;; create the network between banks and cpss  
undirected-link-breed [cps_ccps cps_ccp] ;; create the network between cpss and ccps
```

```
:: Initialization of the variables
```

```
banks-own [  
  bank-credits ;; amount of credits that the bank has  
  bank-reserves ;; amount of reserves that the bank has  
  credit-default-prob ;; probability that a bank suffers from default of its credits  
  bank-credit-loss ;; the loss on credits that the bank incurs  
  bank-loss-to-pass ;; outflow of loss on credits that the bank wants to pass to a cps  
]
```

```
cpss-own [  
  cps-assets ;; amount of assets the credit protection seller has and can sell in case of need  
  cps-reserves ;; amount of reserves that the credit protection seller has  
  cps-assets-loss ;; inflow of loss on assets that the cps should try to recover from others  
  cps-loss-to-pass ;; outflow of loss on assets that the cps wants to pass to others  
]
```

```
ccps-own [  
  ccp-assets ;; amount of assets the central counterpart has  
  ccp-reserves ;; amount of reserves that the central counterpart has  
  ccp-assets-loss ;; inflow of losses on assets that the ccp should try to recover from a cps  
  ccp-loss-to-pass ;; outflow of loss on assets that the ccp wants to pass to a cps  
]
```

```
:: Set-up of the model
```

```
to setup  
  __clear-all-and-reset-ticks  
  setup-banks  
  setup-cpss  
  setup-ccps  
  network-banks  
  network-cpsccps  
end
```

```
to setup-banks  
  create-banks bank-count [  
    set shape "circle"  
    set color red  
    set bank-credits 30 + random 70
```

```

    set bank-reserves 10 + random 20
    set bank-credit-loss 0
    set bank-loss-to-pass 0
    ifelse prob-default-loan = 0 [set credit-default-prob 0] [set credit-default-prob ((prob-
default-loan - 1) * 10 + random 10)]
    move-to one-of patches
]
end

to setup-cpss
  create-cpss cps-count [
    set shape "circle"
    set color blue
    set cps-assets 30 + random 70
    set cps-reserves 10 + random 20
    set cps-assets-loss 0
    set cps-loss-to-pass 0
    move-to one-of patches
  ]
end

to setup-ccps
  create-ccps ccp-count [
    set shape "circle"
    set color green
    set ccp-assets 60 + random 140
    set ccp-reserves 20 + random 40
    set ccp-assets-loss 0
    set ccp-loss-to-pass 0
    move-to one-of patches
  ]
end

to network-banks
  ask banks [create-bank_cps-with one-of cpss]
  repeat bank-connectivity [ask banks [if random 100 < bank-credits [create-bank_cps-with
one-of cpss]]]
  ;; Every bank has at least one connection with a cps
  ;; The higher the connectivity of banks with cpss, the more banks search for additional
connections with other cpss
  ;; Searching for connections with other cpss is more likely if the bank has more credits
end

to network-cpssccps
  ask cpss [create-cps_ccp-with one-of ccps]
  repeat cps-connectivity [ask cpss [if random 100 > cps-assets [create-cps_ccp-with one-
of ccps]]]
  ;; Every cps has a connection with at least one ccp
  ;; The higher the connectivity of cps with other cps, the more cpss search for additional
connections with ccps

```



```
:: Searching for connections with other cpss is more likely if the cps has more assets
end
```

```
:: The general routine of the model
```

```
to go
```

```
if not any? banks [stop]
if not any? cpss [stop]
if not any? ccps [stop]
```

```
ask banks [if bank-reserves <= 0 [die]] ;; banks fail when they are out of reserves
ask cpss [if cps-reserves <= 0 [die]] ;; cpss fail when they are out of reserves
ask ccps [if ccp-reserves <= 0 [die]] ;; ccps fail when they are out of reserves
```

```
ask banks [seek-bank-connections]
ask cpss [seek-cps-connections]
```

```
ask banks [check-bank-losses]
ask cpss [check-cps-losses]
```

```
ask banks [reduce-bank-reserves]
ask cpss [reduce-cps-reserves]
ask ccps [reduce-ccp-reserves]
```

```
ask banks [restore-bank-credits]
ask cpss [restore-cps-assets]
ask ccps [restore-ccp-assets]
```

```
tick
```

```
make-plot
make-plot2
make-plot3
make-plot4
make-plot5
make-plot6
```

```
if layout? [layout] ;; This is to run the graphic display of the financial network
end
```

```
:: The routines to check if banks and cpss have no more connections
```

```
to seek-bank-connections
```

```
  if count my-bank_cpss = 0 [ ;; if the bank has no more connections
    if count cpss > 0 [ ;; if there are cpss
      if bank-credits > 0 [ ;; if the bank has credits
        create-bank_cpss-with one-of cpss ;; create a connectios between the bank and one
      cps
      repeat bank-connectivity [if random 100 < bank-credits [create-bank_cpss-with one-of
cpss]] ;; crete additional connections depending on connectivity
    ]]]
```

end

to seek-cps-connections

```
if count my-cps_cps = 0 [ ;; if the cps has no more connections
  if count cps > 1 [ ;; if there is at least another cps
    if cps-assets > 0 [ ;; if the cps has assets
      ask one-of cps [create-cps_ccp-with myself create-cps_ccp-with one-of other cps] ;;
then a ccp creates connections with the cps and another cps
  if count cps > cps-connectivity + 2 [ ;; if there are enough other cps
    repeat cps-connectivity [if random 100 > cps-assets [ask one-of cps [create-cps_ccp-
with myself create-cps_ccp-with one-of other cps]]] ;; create additional connections
depending on connectivity
  ]]]]
end
```

;; The routines to check if there is any default and what are their consequences on the network

to check-bank-losses

```
if bank-credits > 0 ;; if a bank has some credits
  [if random 100 < (credit-default-prob / 2 + (general-default-risk * 10) / 2) ;; if it
randomly happens that there is a default
  [set bank-credit-loss (bank-credits * default-incidence / 100);; then a loss on credits
happens
  ifelse count my-links > 0 ;; if there are connections with at least one cps
  [set bank-loss-to-pass bank-credit-loss ;; then take note of the loss on credits to pass to
a cps
  ifelse not any? bank_cps-neighbors with [cps-assets > 0] ;; if there are no links to
cps with assets
  [set bank-credits (bank-credits - bank-credit-loss) ;; then compute the loss on credits
of the bank
  ]
  [ask one-of bank_cps-neighbors with [cps-assets > 0] ;; else, ask any linked cps with
assets...
  [set cps-assets-loss [bank-loss-to-pass] of myself] ;; that the cps takes not of
potential loss on their assets
  ]]
  [set bank-credits (bank-credits - bank-credit-loss)] ;; else, then compute the loss on
credits of the bank
  ]]
set bank-credit-loss 0 ;; reset losses on credit of the bank as nil
set bank-loss-to-pass 0 ;; reset losses to pass to cps as nil
end
```

to check-cps-losses

```
if cps-assets > 0 ;; if a cps has some assets
  [if cps-assets-loss > 0 ;; if the cps has some loss on assets passed by another agent
  [ifelse count my-links > 0 ;; if there are links with a ccp
  [set cps-loss-to-pass cps-assets-loss ;; then take note of the loss on assets to pass to a
ccp
```

```

    ifelse not any? cps_ccp-neighbors with [ccp-assets > 0] ;; if there are no connections
to cps with assets
    [set cps-assets (cps-assets - cps-assets-loss)] ;; then compute the loss on assets of the
cps
    [ask one-of cps_ccp-neighbors with [ccp-assets > 0] ;; else, then ask any linked ccp
with assets...
    [set ccp-assets-loss [cps-loss-to-pass] of myself ;; that the ccp takes note of the loss
to pass
    check-ccp-losses] ;; call the routine of the ccp to cover inflow of losses
    ]]
    [set cps-assets (cps-assets - cps-assets-loss) ;; else, then compute the loss on assets of
the cps
    ]]]
    set cps-assets-loss 0 ;; reset losses on assets of the cps as nil
    set cps-loss-to-pass 0 ;; reset losses of the cps to pass as nil
end

```

to check-ccp-losses

```

    ifelse any? cps_ccp-neighbors with [cps-assets > 0] ;; if there is any cps with assets
    [set ccp-loss-to-pass ccp-assets-loss ;; then take note of the loss on assets to pass to a cps
    ask one-of cps_ccp-neighbors with [cps-assets > 0]
    [set cps-assets (cps-assets - [ccp-loss-to-pass] of myself)] ;; compute the loss on assets
of the linked cps
    [set ccp-assets (ccp-assets - ccp-assets-loss)] ;; else, compute the loss on assets on the ccp
    set ccp-assets-loss 0 ;; reset losses on assets of the ccp as nil
    set ccp-loss-to-pass 0 ;; reset losses of the ccp to pass as nil
end

```

;; Routine to transfer losses on credits and assets to reserves

to reduce-bank-reserves

```

    if bank-credits < 0 ;; if a bank has negative credits
    [set bank-reserves (bank-reserves + bank-credits) ;; then reduce bank reserves for the
amount of the negative credits
    set bank-credits 0] ;; reset credits to zero
end

```

to reduce-cps-reserves

```

    if cps-assets < 0 ;; if a cps has negative assets
    [set cps-reserves (cps-reserves + cps-assets) ;; then reduce cps reserves for the amount of
the negative assets
    set cps-assets 0] ;; reset assets to zero
end

```

to reduce-ccp-reserves

```

    if ccp-assets < 0 ;; if a ccp has negative assets
    [set ccp-reserves (ccp-reserves + ccp-assets) ;; then reduce ccp reserves for the amount of
the negative assets
    set ccp-assets 0] ;; reset assets to zero
end

```

:: Routines to let banks, cps and ccp regain some credits and assets over time

```
to restore-bank-credits
  if bank-credits < (bank-reserves * 3) [ ;; if a bank can expand its credits
    set bank-credits (bank-credits + 10) ;; bank credits are slightly increased
  ]
end
```

```
to restore-cps-assets
  if cps-assets < (cps-reserves * 3) [ ;; if a cps can expand its assets
    set cps-assets (cps-assets + 10) ;; cps assets are slightly increased
  ]
end
```

```
to restore-ccp-assets
  if ccp-assets < (ccp-reserves + 3) [ ;; if a ccp can expand its assets
    set ccp-assets (ccp-assets + 10) ;; ccp assets are slightly increased
  ]
end
```

:: The following code draws the plots

```
to make-plot
  set-current-plot "bank count"
  set-current-plot-pen "default"
  plot count banks
end
```

```
to make-plot2
  set-current-plot "cps count"
  set-current-plot-pen "default2"
  plot count cps
end
```

```
to make-plot3
  set-current-plot "total credits of banks"
  set-current-plot-pen "default3"
  plot sum [bank-credits] of banks
end
```

```
to make-plot4
  set-current-plot "total reserves of banks"
  set-current-plot-pen "default4"
  plot sum [bank-reserves] of banks
end
```

```
to make-plot5
  set-current-plot "total assets of cps"
  set-current-plot-pen "default5"
```

```
plot sum [cps-assets] of cpss  
end
```

```
to make-plot6  
set-current-plot "total reserves of cpss"  
set-current-plot-pen "default6"  
plot sum [cps-reserves] of cpss  
end
```

:: The following code draws the network

```
to layout  
;; the number 3 here is arbitrary; more repetitions slows down the  
;; model, but too few gives poor layouts  
repeat 3 [  
  ;; the more turtles we have to fit into the same amount of space,  
  ;; the smaller the inputs to layout-spring we'll need to use  
  let factor sqrt count turtles  
  ;; numbers here are arbitrarily chosen for pleasing appearance  
  layout-spring turtles links (1 / factor) (7 / factor) (1 / factor)  
  display ;; for smooth animation  
]  
;; don't bump the edges of the world  
let x-offset max [xcor] of turtles + min [xcor] of turtles  
let y-offset max [ycor] of turtles + min [ycor] of turtles  
;; big jumps look funny, so only adjust a little each time  
set x-offset limit-magnitude x-offset 0.1  
set y-offset limit-magnitude y-offset 0.1  
ask turtles [ setxy (xcor - x-offset / 2) (ycor - y-offset / 2) ]  
end
```

```
to-report limit-magnitude [number limit]  
if number > limit [ report limit ]  
if number < (- limit) [ report (- limit) ]  
report number  
end
```


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